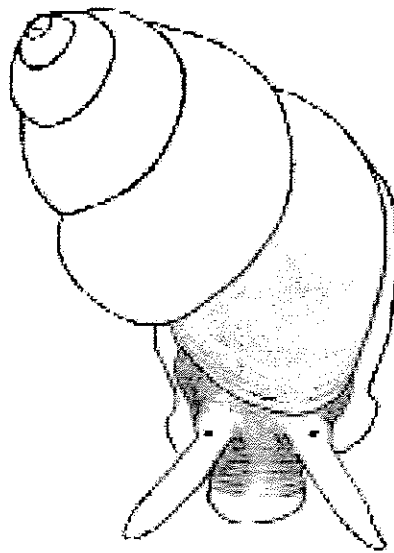
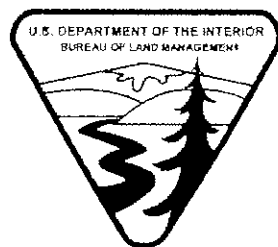


# Field Guide to Survey and Manage Freshwater Mollusk Species

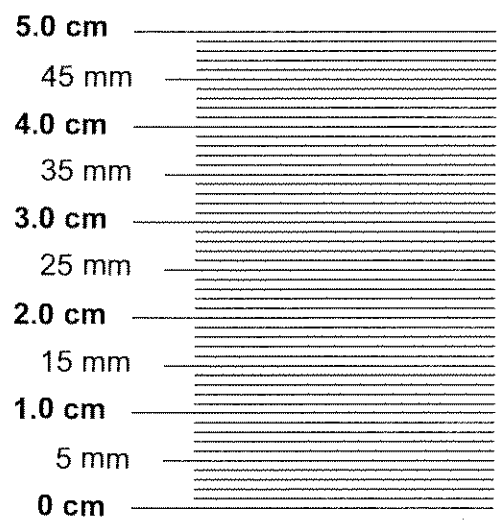
Terrence J. Frest and Edward J. Johannes



**Lyogyrus** n. sp. 2 (Washington dusksnail)  
scale bar length 1 mm



**BLM/OR/WA/PL-99/045+1792**



# **Field Guide to Survey and Manage Freshwater Mollusk Species**



Terrence J. Frest and Edward J. Johannes<sup>1</sup>

September 30, 1999

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# **FIELD GUIDE TO SURVEY AND MANAGE FRESHWATER MOLLUSKS**

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## **INTRODUCTION**

This field guide is intended for use in identification of the 19 currently recognized (September, 1999) ROD (1994) [Record of Decision] Survey and Manage freshwater mollusks. All of the Survey and Manage taxa are freshwater gastropods (snails). The basic arrangement is taxonomic, following that in Turgeon *et al.* (1998). Snail descriptive terminology is unfamiliar to many and not completely standardized. In this work, we follow Hershler & Ponder (1998) for hydrobiids, the majority of the Survey and Manage species. Other terminology may be derived from Burch (1989), which see: a more comprehensive overview of terminology is provided in Frest & Johannes (in press) and in Arnold (1965). Also consult the **GLOSSARY** at the end of the text.

Identification of these animals is complicated by their relatively small size; many are less than 4 mm in maximum dimension. Also complicating matters is the fairly large number of possibly co-occurring, non-ROD taxa (or at least non-Survey & Manage; many of these other taxa, as well as most Survey & Manage taxa, are Riparian Reserve or otherwise special-status species). In fact, there is a real possibility that the user will encounter species not known to the authors at the time this field guide was compiled. Fortunately, most Survey & Manage taxa occur in relatively well-surveyed drainages. Quite often, detailed recent reports (e.g., Frest & Johannes, 1995a, 1998a, in press: see **REFERENCES**) will be available for the drainages in which the Survey & Manage taxa are found. Consultation with these may be very helpful.

To help simplify the identification process, we have included six detailed keys. **Keys 1-3** cover sets of *Fluminicola* endemic to particular large drainages, specifically those of the Upper Klamath Lake area, southern Oregon, 3 Survey & Manage freshwater mollusk taxa); the Upper Sacramento River - Pit River drainage, northern California (8 such taxa), and the middle Klamath River-Jenny Creek drainage, southern Jackson County, Oregon and adjacent northern Siskiyou County, California (1 taxon). In each of these cases, a large swarm (> 7) of endemic *Fluminicola* species is known to be present, of which only a few are Survey & Man

age taxa. The keys cover all known *Fluminicola* species from each endemic region. Note that these keys cover very specific geographic areas: they should not be used outside of these areas, even for streams immediately adjacent to them. The remaining three keys cover the less speciose genera. **Key 4** includes all western US species in the hydrobiid subfamily Amnicolinae. This group has “*Lyogyrus*”, with 3 Survey & Manage taxa, as a constituent. **Key 5** covers Survey & Manage and related taxa in the family Pleuroceridae; here, 2 taxa, both in the genus *Juga*, are involved. Finally, **Key 6** covers all known species of the planorbid genus *Vorticifex*, which includes 2 Survey & Manage taxa.

## GENERAL FEATURES OF FRESHWATER SNAILS

It is useful to know both some common features of freshwater snails (gastropods) and certain specialized characteristics of the ROD taxa in order to make identification easier, especially in the field. Terminology for shell and body morphology has varied considerably through time and is still not completely formulaic. That used here will be derived largely from two sources: Burch (1989) generally, Hershler & Ponder (1998) for hydrobiids. Frest & Johannes (in press) make a few modifications and additions. The first and third cited sources each have glossaries; one is provided here also to clarify usage. In the following discussion, bold-face words are likely to be defined further in the **GLOSSARY**. Keep in mind that older literature, and some current, may employ different terms. To keep this guide user-friendly, we emphasize shell terminology and external body morphology. Readers wishing more detail should note that anatomical features or, less often, biochemical properties, are the most important determinants.

All freshwater snails have a shell, a hard structure covering most of the body, providing protection. That shell normally consists of several layers, one to several mineral (calcium carbonate, usually aragonite or calcite) and one outermost (**periostracum**), composed mostly or entirely of organic material and usually pigmented. The shell is basically a tube coiled variously around a central pillar, termed an **axis**. Each complete turn is called a **whorl**: generally, the first 1 or 2 whorls are formed before the snail egg hatches and are termed **embryonic**, or **nuclear**, whorls. Collectively, these make up the **protoconch**. Often, coiling and surface morphology of these whorls are different from those that follow, termed **postembryonic** or **teleoconch** whorls. While most mollusks do not have determinant growth, strictly speaking, the total number of whorls and

shell size are pretty stable features of sexually mature individuals of each species. Adults seem to put much of their physiological efforts into gamete production instead of growth. The whole shell is termed the **conch**; all whorls except the last one make up the **spire**. The final (last, ultimate) whorl often differs in morphology in some way from those preceding, most often in terms of **aperture** (mouth; shell opening proper: the rim or border itself is termed the **peristome**) features. This is mostly the case if the animal is mature; descriptions without specification always refer to mature (adult; sexually capable) individuals. The whorl preceding may also be discriminated as the **penultimate** whorl. The line of contact between adjacent whorls is the **suture**. Usually, it is sunken to some degree, *i. e.* **impressed**. Whorl profile is important, also. Generally, a whorl in side view is rounded to some extent; if very evenly so, it is **convex**; often, whorl shape is flattened to some degree. The whorl **periphery** may be even, so that the outermost point is at midwhorl; or it may be **shouldered** to varying extent, with the outermost point displaced adapically or abapically.

Shells are generally oriented with the earliest whorls uppermost (north: **Figure 1**) and the aperture and peristome directly facing the observer. In such an orientation, the top (earliest formed whorls) is the shell **apex**; the aperture of a **dextrally** (right) coiled shell will be to the observer's right (east) and of a **sinistrally** coiled shell to the observer's left (west). In this position, the direction toward the shell apex is termed **adapical** (with the animal in the shell, this would be **posterior**: **Figure 2**) and movement toward the shell base or aperture is termed **abapical** (with the animal included, this is the **anterior** end). With or without the animal, there are left or right sides to the shell (and animal); apertural terminology differs, however. With the animal, the base of the aperture is termed anterior and the summit (often angled) posterior. In shell-only terms, aperture and peristome terminology is more complicated, as a number of shell modifications commonly are seen at this location. In freshwater forms, these are more simple than in marine; so only the minimum terminology is used here. The peristome has four quadrants, a **basal**; that along the **columella** (that part of the shell directly around the axis, mostly covered but including a part exposed at the aperture; often pillar-shaped), termed **columellar**; a **parietal** portion where the last whorl meets or approaches the preceding; and an **outer**. The peristome portions are **walls** or **lips**, with the appropriate specifier added. Degree of contact with preceding whorls varies and so affects the parietal wall; contact mostly or all along is **appressed**; minor contact is **adnate**; with none, the whorl portion and wall are **disjunct**. Obviously, degree of contact may affect sutural mor

phology and other features such as aperture shape also. There is a range of terms, mostly common-sense, to describe apertural shape, such as circular; angular; **lunate** (shaped like a crescent moon), etc. (see Burch, 1989, fig. 9 for one useful scheme). Appressed-aperture forms tend to have the posterior aperture angular to varying degrees; strongly disjunct apertures are usually circular. The peristome may be simple and thin; or it may be differently reinforced with extra mineral matter in various ways. Most commonly, it is the columellar peristome or wall that is reinforced and the parietal not; the basal and outer walls may also be. In hydrobiids, the columellar reinforcement is termed a **columellar shelf**. As might be expected, other modifications are also more or less restricted to the columellar area. Important here is the **columellar furrow** (Figure 1) of some hydrobiids and a few other taxa. The columellar furrow is an excavated area to the left of the columella, beginning at some point (not necessarily basal) on it and terminating adapically, often in the umbilical area but sometimes extending across the parietal wall. The columellar furrow is often lunate or wedge-shaped (almost always narrower abapically); the left border is the **columellar ridge** and the right border is the left edge of the columellar shelf or wall and/or parietal wall. The area in between often bears growth lines or **columellar grooves** and is dark-colored. Rarely in freshwater forms, the peristome may have extra complications, such as raised **lamellae** (teeth; denticles; nodes), furrows or plaits; again, these are most often seen on the columellar wall. The aperture as a whole may vary in orientation between taxa: if the upper or adapical part leans forward instead of being planar, it is **prosocline**; if the lower (basal, abapical) portion is so advanced, it is **opisthocline**. The aperture edge may be straight or curved in side view; it may terminate sharply and evenly; or be expanded, **reflected**, or even begin to roll (**revolute**).

The axially-positioned opening at the shell base, if present, is the **umbilicus**. Its size and morphology also provide diagnostic characters for many taxa. If covered, the shell is **anomphalous**; otherwise it is **phaneromphalous**. If the aperture lip partly covers the umbilicus, the latter is **rimate**; a really minute open umbilicus is termed **perforate**.

Rate of whorl expansion is also significant; generally, it is termed **rapid** if few whorls are required for the adult or **slowly increasing** if whorls are many and have subparallel sides instead of the outer noticeably diverging. Other details of shell shape and sculpture have similarly elaborate terminology, especially if the character involved is useful for taxonomy. Shell shape is usually described by such names as conic; trochoid;

turbinate; globose; depressed; or discoidal, often with modifiers such as high, low, moderately, sub-, narrowly, globosely, etc. (for illustrations of most of these, see Burch, 1989, figs. 4-5). More precisely, a shell may be termed narrowly conic if the sides make an acute angle with the apex of roughly 20°; around 30° would be elongately conic; roughly 60° ovately or broadly conic; 70° or so globosely conic; and over 90° depressed conic. Description of the whorl **translation** rate, or rate of downward coiling relative to the axis, is also helpful. Quite often, the initial whorls (protoconch) coil differently than the later whorls; sometimes, the ultimate whorl also coils differently than the other teleoconch (spire) whorls; and occasionally, other spire whorls may change translation rate more than once during ontogeny.

Sculpture is particularly evident in the periostracum; but some features continue into, or originate in, the inorganic layer(s). Periostracal and shell thickness and color (mostly in the periostracum) and opacity or translucence are significant. Sculptural features may be divided into two general classes, depending upon whether they are aligned primarily parallel to the aperture (radially or transversely across the whorl) or at a right angle to it (in the direction of coiling; spirally). Ribs may be fine to coarse: a spiral rib is a **lira** (plural **lirae**); coarse transverse ribs are **costae** (singular **costa**); these are solid raised features, while hollow elongate raised transverse features are **plicae** (singular **plica**). Sharp or strongly raised spiral ribs are **carinae** (singular **carina**); one or a few major regularly positioned angular "plicae" spiral on the whorl periphery may be **keels**. Other ornament may include knobs or nodes. Depressed lineate features are **striae** (singular **stria**) when fine, as they usually are; shells with such features are **striate**, **carinate**, etc. Almost all shelled gastropods have transverse, often **collabral** (parallel with the aperture lip) growth lines. These are usually somewhat irregular (if completely regular, they are transverse sculpture) and often rather fine. Growth lines may be orthocline (parallel to the shell axis), **prosocline**, or opisthocline, even if the aperture proper is oriented differently. Occasionally, shell sculpture may be **punctate** (small pits) or **reticulate** (crossed transverse and spiral ribs). Sometimes, extra periostracum, often brown, may accentuate raised sculptural features into fringes or hairlike structures (periostracal **setae**). Many of these conditions are illustrated in Burch (1989, fig. 7). Other surface features may include malleations or wrinkles or development of spines or nodules.

The corneous cover which some taxa can use to seal the aperture is termed an **operculum**. Depending on number of whorls, it is

**paucispiral** or **multispiral**; if the nucleus is central, it is generally **concentric**; it may instead have an **excentric** or **submarginal** nucleus. Shape varies, mostly with aperture shape.

The body (**Figure 2**) consists in hydrobiids of a head-foot and mantle (**visceral coil**) regions. The former includes a head, with **snout**; **cephalic tentacles**; and eye spots, either on lobes or not; neck; and foot, with opercular lobe posterior and anterior propodium and mucus gland. Female genitalia are mostly interior; male genitalia include an exterior portion consisting of a penis, with or without accessory lobe, glands, etc. Body pigment patterns are significant; and can be described in detail. For much more involved terminology for this and other features, see Hershler & Ponder (1998, figs. 1-17). However, the smaller number of terms used consistently here should be sufficient for good identification of the ROD taxa.

Various descriptions of collection and relaxation methods are available. One is the Forest Service-BLM draft protocol for Northwest Forest Plan aquatic mollusk surveys (Furnish, Monthey, & Applegarth, 1997); others include Frest & Johannes (1995a, in press).

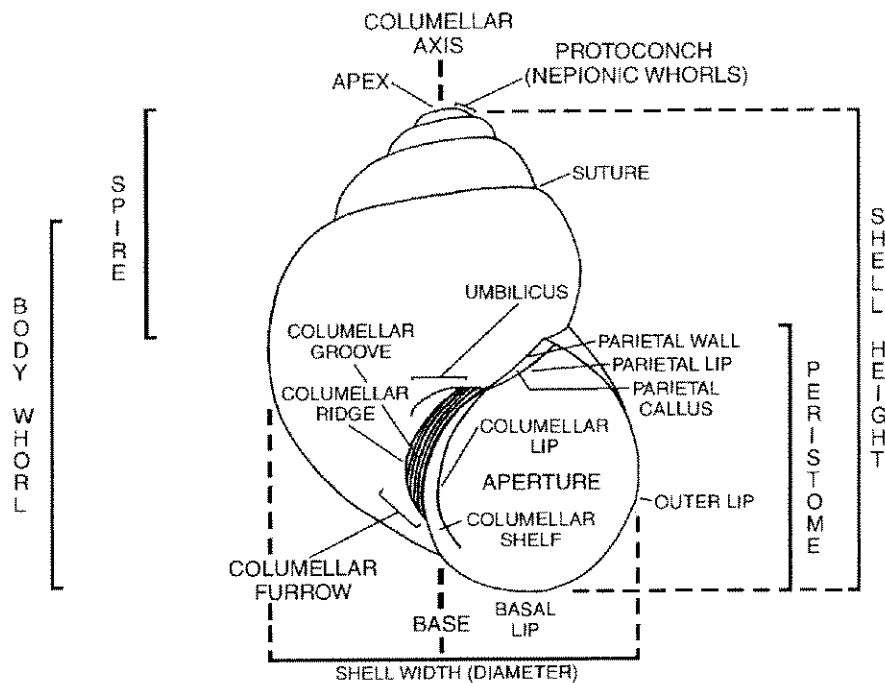


Figure 1. General Features of Freshwater Gastropod shell (hydrobiid; Lithoglyphinae: idealized Fluminicola). Approximate shell height 4.0 mm.

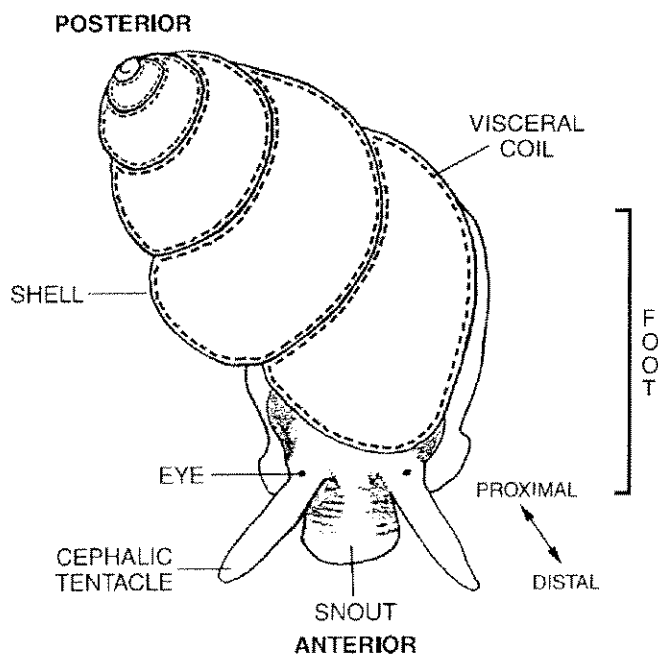


Figure 2. General Features of Freshwater Gastropod animal (hydrobiid; Amnicolinae: Lyogyrus n. sp. 2). Actual shell height 3.3 mm.

## OVERVIEW OF SURVEY AND MANAGE FRESHWATER SNAILS

There may be as many as 200 freshwater gastropod taxa in the range of the Northern Spotted Owl. The likely total number of genera is about 30 (Frest & Johannes, in press). For general keys to western US freshwater gastropods, see Frest & Johannes (1999, in press) and Burch (1989). For common names and taxonomic lists of presently accepted species and genera (but not subspecies), see Turgeon *et al.* (1998). More useful here is a brief description of the four genera with Survey & Manage taxa and the families to which they belong. Note that, at present, there is no complete guide to western US freshwater mollusk species and that perhaps 50% are undescribed. Addition of new forms is taking place rapidly, so that the recent malacological periodical literature should also be watched for new relevant works.

Two genera of especial concern here are in the rissooidean family Hydrobiidae. This is a very large worldwide group of over 400 recent and fossil genera and 1,000 species (Hershler & Ponder, 1998). Higher classification is currently not completely resolved; but a general framework of morphological characters has been proposed (Hershler & Ponder, 1998) and is used here. These small spring, stream, lake and cave snails, often called **hydrobiids**, generally have a solid shell with thin periostracum and a horny operculum. Most are small (under 2 cm height); US forms are often under 1 cm in height. Many have separate sexes but the shells are not commonly dimorphic. The majority have a conical spire; but flat, trochoid, neritiform, and uncoiled forms are known. In the northwestern US, there are four common genera: *Fluminicola*, "*Lyogyrus*", *Pyrgulopsis*, and *Pristinicola*.

*Pristinicola hemphilli*, the pristine pyrg, is a small, pupa-shaped form (length 1.5-3.0 mm) with a white shell and almost pigmentless animal (note: at present, there is only one species of *Pristinicola*). The verge is a simple elongate glandless penial filament with a vas deferens. *Pristinicola* occurs commonly in very small springs, seeps, and springs; and need not concern us further here. For description and illustrations, see Hershler *et al.* (1994). *Pristinicola* appears to be an **annual** (one-year life cycle) form with very small individual egg capsules, generally laid on rock undersides in sheltered areas. The snails are primarily **aufwuchs** grazers in cold to very cold clear shallow waters with few **macrophytes**, hard



substrate, and high water quality. *Pristinicola* is not a Survey & Manage taxon.

*Pyrgulopsis*, the pyrgs and springsnails proper, is a large genus with over 100 western species known. Most of these are found in the Great Basin; the few found here are mostly high conical snails 2-5 mm high. As with all hydrobiids, the shell form is simple, so that taxonomy is mostly based on soft parts. *Pyrgulopsis* generally has an elongate snout and long tentacles; and the verge generally has one or more glandular areas. It may consist of a (often stout) penial filament only; or, more frequently, a penial filament and blunt accessory lobe. The periostracum is often grey, bluish, tan, yellow, or other colors (seldom with any color pattern). For excellent coverage, see Hershler (1994, 1998) and references therein. This genus commonly appears to be annual; it lays small, hemispherical egg capsules with single embryos in each, often in protected situations on hard substrate. Most species seem to be aufwuchs grazers, and the genus is particularly characteristic of cold springs, although amniphile and thermophile taxa do occur as well. None of these springsnails are Survey & Manage taxa.

*Fluminicola* has about 7 described species and about 50 undescribed. The so-called pebblesnails fall into two groups, one generally 2-5 mm high and the other often 5-12 mm high. Both tend to have an evenly yellow or green solid shell, often low conical in shape. The snout is broad and cephalic tentacles short. The male verge has a non-glandular penial filament only. This may be broad and triangular; long and sickle-shaped; or blade-like with a prominent wing on the left side. Most species have dark-pigmented cephalic tentacles and distal snout; but some have completely black bodies and a few lack dark pigment. *Fluminicola* may be found in streams of all sizes (usually the larger species group) or in cold springs (often but not always the smaller forms). This genus includes some of the most abundant, widespread, and characteristic northwestern US freshwater snails; and 12 ROD species (Table 1). Many are lithophiles; but some can tolerate soft substrate. Most species seem to have an annual life cycle; eggs are laid as individual, low hemispherical capsules. The most recent revision is Hershler & Frest (1996).

"*Lyogyrus*" is the term currently applied to most small northwestern US amnicolinids. This name was coined for eastern US forms: Hershler (in press) reassigns two western taxa to a new genus; and most probably will be placed there eventually. The duskysnails are so called because their shells often have a partial or complete dark mineral coating. They are often very small (3 mm length or less); have thin shells, often with low

conical spires, and are somewhat secretive in their habits, perhaps because some are **photophobic**. Many have little body pigment. The thin shell is often transparent; and the color an even yellow, tan, whitish, or orange. The verge consists of two non-glandular lobes, a generally long, thin penial filament and a narrow accessory lobe, originating at the base of the penis; neither is glandular. There are about a dozen western US species, most discovered in the last decade. Favored habitats include very cold springs and streamlets and sheltered areas of large, rocky limnocrenes. They are almost always lithophiles. Three Survey & Manage taxa (**Table 1**) are covered in detail here.

These diminutive snails are most often found on rock undersides (although one species prefers deciduous leaves and two can live on soft substrates). The egg capsules are single and have a prominent longitudinal ridge. Most species appear to have an annual life cycle.

Western US streams and springs often have incredible numbers of larger (2 to 5 cm long) thick-shelled, very high-spined snails, often with many whorls and a dark appearance overall due to mineral deposits. Beneath these, the periostracum is often yellow or greenish-yellow (can be cinnamon or brown); and there are frequently a few broad red or tan spiral stripes. Aperture nacre can be clear, brown, white, purple, or striped and ranges from transparent to opaque. These are the pleurocerids of the genus *Juga* (common name also juga), often the dominant single invertebrate species in terms of numbers and mass in pristine, level, cold-water streams (Hawkins & Furnish, 1987). Aside from the high spire and large size, the small operculum is characteristic. The snout is blunt and short; and the cephalic tentacles long, slender, and active. The body groundcolor is generally dark; when alive, the body is often densely and finely striped with yellow or orange. As preserved, the body is generally blue, grey, or black. There are no obvious external genitalia, even when well-relaxed.

At present, about 30 forms are recognized, less than a dozen of which are described. Embryonic whorls are always smooth and variously convex. There are three subgenera, distinguished by very early postembryonic whorl morphology. *Juga* (*Juga*) has many prominent, regularly arranged transverse plicae; *Juga* (*Oreobasis*) early whorls smooth or with a few low, scattered plicae; and *Juga* (*Calibasis*) several strong radial ribs. For illustrations of described forms, see Burch (1989); for currently known taxa, see Frest & Johannes (in press). These snails likely live 2 to 7 years. The egg masses are unordered finger-like strings or more irregular, elongate masses with thousands of individuals in each. *Juga* seems

capable of easy survival on both soft and hard substrates, as long as the stream or spring concerned is oligotrophic and has water of high quality. Species may consume either deciduous leaf fall-in *speriphyton*, aufwuchs, or all three. Two undescribed species in *Oreobasis* are Survey & Manage species (Table 1).

Most eastern US planorbids are warm, still water forms; but the dominant cold oligotrophic flowing water regimes of the northwestern US have produced a response in this family with the endemic genus *Vorticifex*. Of the dozen or so known taxonomically distinct forms, two are Survey and Manage taxa (Table 1). *Vorticifex* has a low, often almost limpet-like spire with a few, rapidly expanding whorls. It is most common in flowing water situations with hard substrate and good or excellent water quality. The shell is thin and low and most often dark reddish-brown in color and 1-2 cm in width. *Vorticifex* is essentially annual, laying low, tough circular egg capsules on rocks, often in protected situations. Each capsule may contain from 6 to 30 or so embryos. The best references are Baker (1945) and Frest & Johannes (in press).

For correct freshwater gastropod identification, relaxed, fully grown adults may be necessary. Dead shells may change in color and other morphological features. Shell color is preserved in alcohol; but body pigment, except for black (melanin), may be lost quickly in preservatives. For these reasons we emphasize fresh shell features and the more permanent body features here. Note that formal descriptions are generally based upon alcohol-preserved specimens, in which the body proportions and appearance may also differ from live material. For most of these taxa, at least a few adults should be present year-round; but late spring or late fall collection sometimes may be necessary to ensure that many adults are taken. In many *Fluminicola*, the peristome is thin until the onset of maturity, at which point one or more apertural walls may be thickened along the periphery (a few begin to do this early on); many *Juga* and *Vorticifex* do likewise, particularly with the columellar lip. As these animals do not much modify the simple shell at maturity, sexual maturity may also be used to define adulthood. This is determined by the presence of mature, external male genitalia for *Fluminicola* and "*Lyogyrus*" on some properly relaxed specimens. Similar considerations apply for the male genitalia of the hermaphroditic *Vorticifex*. *Juga* is more difficult, as even relaxed specimens may be gender-cryptic; and there is no external male verge. In general, here and with the other genera, there should be a substantial class of large specimens present at a site, which normally should be adults. While anatomical considerations are paramount for accurate

taxonomy, shell characters are often sufficient. The most important features will be discussed below. Still, it is best to at least examine the external body morphology, including shape of cephalic tentacles and snout; morphology of relaxed male genitalia (if any); and body color and distribution of black pigment on the extruded portions of the body and on the surface of the visceral coil. The body can be removed from the shell by boiling if relatively fresh; for long-preserved specimens, the body must be freed by dissolving the shell in acid, formalin, Bouin's Solution, or similar agents; or by careful crushing.

**TABLE 1. Summary Information for Survey and Manage Freshwater Mollusks.**

ROD SCIENTIFIC NAME	ROD COMMON NAME	R6 CODE
<i>Fluminicola n. sp. 1</i>	<i>Klamath pebblesnail</i>	FLNS50
<i>Fluminicola n. sp. 2</i>	<i>tall pebblesnail</i>	FLN950
<i>Fluminicola n. sp. 3</i>	<i>Klamath Rim pebblesnail</i>	FL1150
<i>Fluminicola n. sp. 11</i>	<i>Fredenburg pebblesnail</i>	FLN150
<i>Fluminicola n. sp. 14</i>	<i>Potem pebblesnail</i>	FLN350
<i>Fluminicola n. sp. 15</i>	<i>flat-top pebblesnail</i>	FLN450
<i>Fluminicola n. sp. 16</i>	<i>Shasta Springs pebblesnail</i>	FLN550
<i>Fluminicola n. sp. 17</i>	<i>disjunct pebblesnail</i>	FLN650
<i>Fluminicola n. sp. 18</i>	<i>globular pebblesnail</i>	FLN750
<i>Fluminicola n. sp. 19</i>	<i>umbilicate pebblesnail</i>	FLN850
<i>Fluminicola n. sp. 20</i>	<i>Lost Creek pebblesnail</i>	FL1050
<i>Fluminicola seminalis</i>	<i>Sacramento pebblesnail</i>	FLSE50
<i>Juga (Oreobasis) n. sp. 2</i>	<i>basalt juga</i>	JUNS50
<i>Juga (Oreobasis) n. sp. 3</i>	<i>cinnamon juga</i>	JUN150
<i>Lyogyrus n. sp. 1</i>	<i>Columbia duskysnail</i>	LYNS50
<i>Lyogyrus n. sp. 2</i>	<i>Washington duskysnail</i>	LYN150
<i>Lyogyrus n. sp. 3</i>	<i>canary duskysnail</i>	LYN250
<i>Vorticifex klamathensis sinitsini</i>	<i>Sinitsin rams-horn</i>	VOKL50
<i>Vorticifex n. sp. 1</i>	<i>knobby rams-horn</i>	VONS50

## SPECIES DISCUSSIONS

Each of the 19 currently recognized ROD Survey & Manage freshwater mollusks (see **Table 1** for summary) has a separate entry below. Species are arranged by family, then alphabetically. A **Key** precedes each group (ROD Survey & Manage taxa are highlighted in bold face type). Species entries share a common format: a short **DESCRIPTION** emphasizing shell features; a **DISCUSSION** of relationships and similar forms; information on **ECOLOGY**, habitats, and associates; an **ORIGINAL DISTRIBUTION** section on probable historic range; a similar section, **CURRENT DISTRIBUTION**, on presently known sites; and a short **REFERENCES** review. Illustrations in the form of a drawing, a photograph, and a distribution map for each taxon precede each text entry. Note that some genera may have organic or inorganic material coating part or all of the shell (periostracum). This has been removed, or naturally clean specimens have been used, for the drawings and descriptions; but not necessarily for all of the photographs. Specimens should be cleaned **only** when absolutely necessary, generally with a small brush with firm bristles and such liquids as hydrogen peroxide, bleach, or soap.

### *FAMILY HYDROBIIDAE*

#### Key 1. Upper Klamath Lake drainage *Fluminicola* species [Survey & Manage: *Fluminicola* n. sp. 1, 2, 3]

About 11 species of *Fluminicola* (s.l.) are currently known from the Upper Klamath Lake drainage. All appear to be endemic to the Klamath Basin and undescribed. A few others are likely to be discovered. For information on Upper Klamath Lake drainage species to date, see Frest & Johannes (1995b; 1996b; 1998a). These taxa are best discriminated by anatomic criteria; but shell characters can be used also. For example of more complete description of *Fluminicola* (s.l.), see Hershler & Frest (1996). Western US material thought possibly belonging to either the Pomatiopsidae or Lithoglyphinae, with the possible exception of the taxa covered in Hershler & Frest (1996), should be relaxed and preserved and examined by specialists. This key does not cover all known and likely species; but should eliminate the non-Survey and Manage taxa and allow tentative identification of middle Klamath-Upper Klamath Lake drainage Survey and Manage taxa. Identification of extralimital taxa, even in immediately adjacent drainages, should not be attempted using this key; and addition of

other taxa will require its modification (for example, see Upper Sacramento drainage key below). Because various number schemes have been applied to the undescribed taxa, only those used for the ROD (1994) report are used here [n. sp. 1-3; in **bold** in the key]; the remaining taxa are numbered as in Frest & Johannes (1996b, 1998a, in press). For Middle Klamath (Jenny Creek-Fall Creek) taxa, see **Key 2**.

- 1 Shell comparatively large, over 7 mm height ..... 2  
 Shell comparatively small, generally under 7 mm height ..... 5
- 2 Body light in color; tentacles and eye patches dark ..... 3  
 Body dark in color; tentacles and eye patches dark ..... 4
- 3 Penis sickle-shaped; shell tall subglobose; whorls convex;  
 yellow-green; closed umbilicus ..... *Fluminicola* n. sp.  
     **1 [Fluminicola n. sp. 1 Frest & Johannes, in press]**  
 Penis alate from midpoint distally; shell globose, whorls evenly  
 convex; closed umbilicus ..... *Fluminicola* n. sp. 8  
     Frest & Johannes, in press
- 4 Penis sickle-shaped, pigmented basally .....  
     ..... *Fluminicola* n. sp. 27 Frest & Johannes, in press  
 Penis alate basally on left side .....  
     ..... *Fluminicola* n. sp. 28 Frest & Johannes, in press
- 5 Shell tall-medium conical, to 7 mm height ..... 6  
 Shell low conical to globose ..... 7
- 6 Shell tall conical; to 5 mm height; adult spire decollate; penis  
 unpigmented, alate ..... *Fluminicola* n. sp. 2 [*Fluminicola* n. sp.  
     **2 Frest & Johannes, in press]**  
 Shell medium conical, decollate; to 7 mm if complete; penis  
 broad sickle-shape; subepithelial bar; light epithelial pigment  
 to end; tip papillate ..... *Fluminicola* n. sp. 42 Frest &  
     ..... Johannes, in press
- 7 Shell low conic ..... 8  
 Shell subturbinate to globose ..... 11
- 8 Shell low conic; < 2 mm height; gray body and tentacles; thin,  
 sickle-shaped penis ..... *Fluminicola* n. sp. 3  
     **[Fluminicola n. sp. 3 Frest & Johannes, in press]**  
 Shell low conic; > 2 mm height ..... 9

- 9 Umbilicus closed; whorls convex; dark gray body and black tentacles; moderately large, sickle-shaped penis with basal folds; aperture rounded, barely reinforced .....  
..... *Fluminicola* n. sp. 7 Frest & Johannes, in press  
Small open umbilicus ..... 10
- 10 Shell smaller (ca. 2 mm height); blunt-topped; distinctly open umbilicus ... *Fluminicola* n. sp. 9 Frest & Johannes, in press  
Shell large (to 3 mm height); taller; very small open umbilicus .....  
..... *Fluminicola* n. sp. 31 Frest & Johannes, in press
- 11 Gray body and tentacles; shell with evenly convex whorls; penis sickle-shaped, unpigmented .....  
..... *Fluminicola* n. sp. 29 Frest & Johannes, in press  
Gray body and tentacles; shell with subangulate periphery; penis broadly alate, pigment spots and bars .....  
..... *Fluminicola* n. sp. 30 Frest & Johannes, in press





*Fluminicola* n. sp. 1

[*Fluminicola* n. sp. 1 Frest & Johannes, in press]

## Klamath pebblesnail

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### DESCRIPTION

See Frest & Johannes (1995a; 1998a, in press) for description; also consult **Key 1** above. Conch tall subglobose (**Figures 3 & 4**); adults with about 5.25-5.75 whorls; shell height usually between 8.0-10.2 mm; width 6.2-7.5 mm; H/W ratio 1.31; shell moderately thick; whitish; periostracum yellow, yellow-green, or yellowish tan; sculpture consists of very weak, slightly irregular growth lines only; protoconch generally with about 1.5 whorls; diameter ca. 0.31 mm; almost flat, small in relation to rest of shell; post-embryonic whorls coiled consistently; teleoconch whorls slightly flattened convex, with periphery central, not shouldered; suture deeply impressed; aperture large, height to 0.48 total shell height, broadly lunate, narrowed above; complete (thin glaze only across parietal wall) outer lip usually thin; parietal lip mostly thin (glaze) except for small area adjoining umbilicus; appressed, in contact with preceding whorl for full length; columellar swelling moderately thick, barely covering umbilicus; shelf does not continue basally; columellar ridge moderately developed; subparallel to columellar lip; extending almost full length of columellar lip; moderately wide, width equal to or less than width of columellar callus; shell typically anomphalous; body as preserved with dark tentacles, anterior and posterior edge, and snout but light body; and penis sickle-shaped, moderately large.

This is a large (i.e., > 5 mm height) *Fluminicola* species, often with yellow to yellowish-brown periostracum. Live specimens have the eye patches bright canary yellow; this fades completely within a few days in preserved material. The combination of a large, tall subglobose conch with slightly flattened whorls and sickle-shaped penis are distinctive in the Upper Klamath Lake region; other similar species have an alate penis, green periostracum, and/or completely pigmented (black) body (except for eye spots).

### DISCUSSION

This taxon was cited as *Fluminicola* n. sp. 1 in Frest & Johannes (1993c, 1995a, b, 1996a, b, 1998a): see Table 6 (Frest & Johannes, in press). It may be present in some collections under the name *F. seminalis*. About 22 sites are currently known: see **Map 1** and reference below to detailed map of presently recognized sites.

## ECOLOGY

This species occurs in Upper Klamath Lake, a few major tributaries, and part of the Klamath River, generally in areas with gravel-boulder substrate, spring influx, and some flow. Like most *Fluminicola*, this species prefers clear, cold, oligotrophic flowing water with high DO. It is found only rarely in springs and avoids areas with dense macrophyte beds. It sometimes occurs with other endemic *Fluminicola* spp., *Lanx alta* or *Lanx klamathensis*, *Lyogyrus* spp., *Helisoma* (*Carinifex*) *newberryi*, or *Pisidium ultramontanum*. Predominantly a perolithon grazer and lithophile; but may sometimes be found on oxygenated mud substrate, especially if firm.

## ORIGINAL DISTRIBUTION

Klamath River, Siskiyou County, California, and Klamath County, Oregon; Upper Klamath Lake, Klamath County, Oregon; probably once very widespread in this area.

## CURRENT DISTRIBUTION

Middle and upper Klamath River, but now very sporadic (absent from impoundments and polluted stretches), Siskiyou County, California; Upper Klamath Lake and major spring-fed tributaries, Klamath County, Oregon, including sites in Winema National Forest and Upper Klamath Lake National Wildlife Refuge. Other localities are on Lakeview District BLM lands. See **Map 1**; for detailed map, see Frest & Johannes (1995c, map D2).

## REFERENCES

Frest & Johannes (1993c; 1995a, c; 1996a, b; 1998a; in press); Deixis collections, 1991-1999.



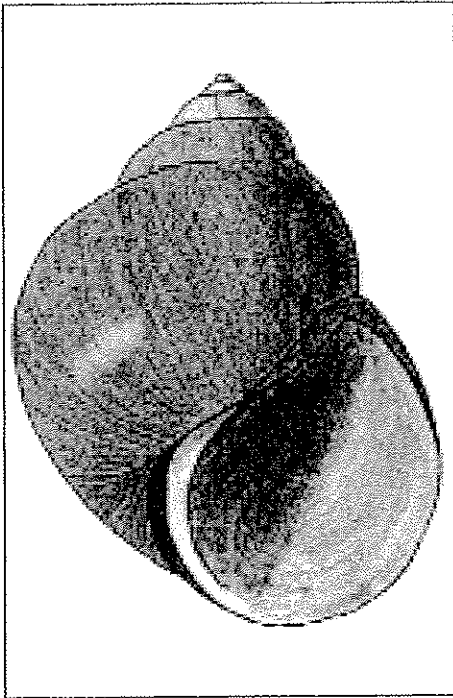


Figure 3. *Fluminicola* n. sp. 1:  
actual height 8.4 mm.

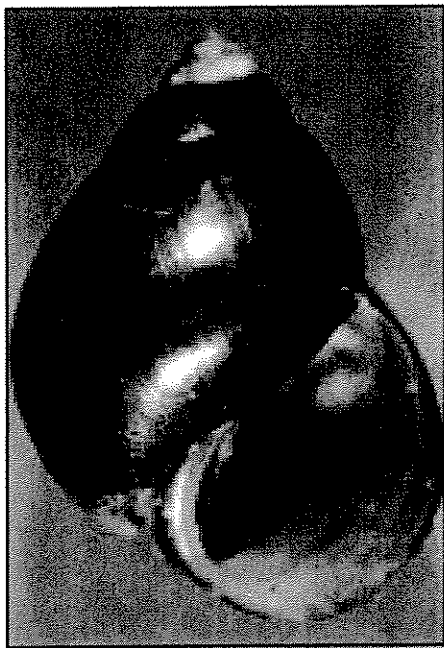
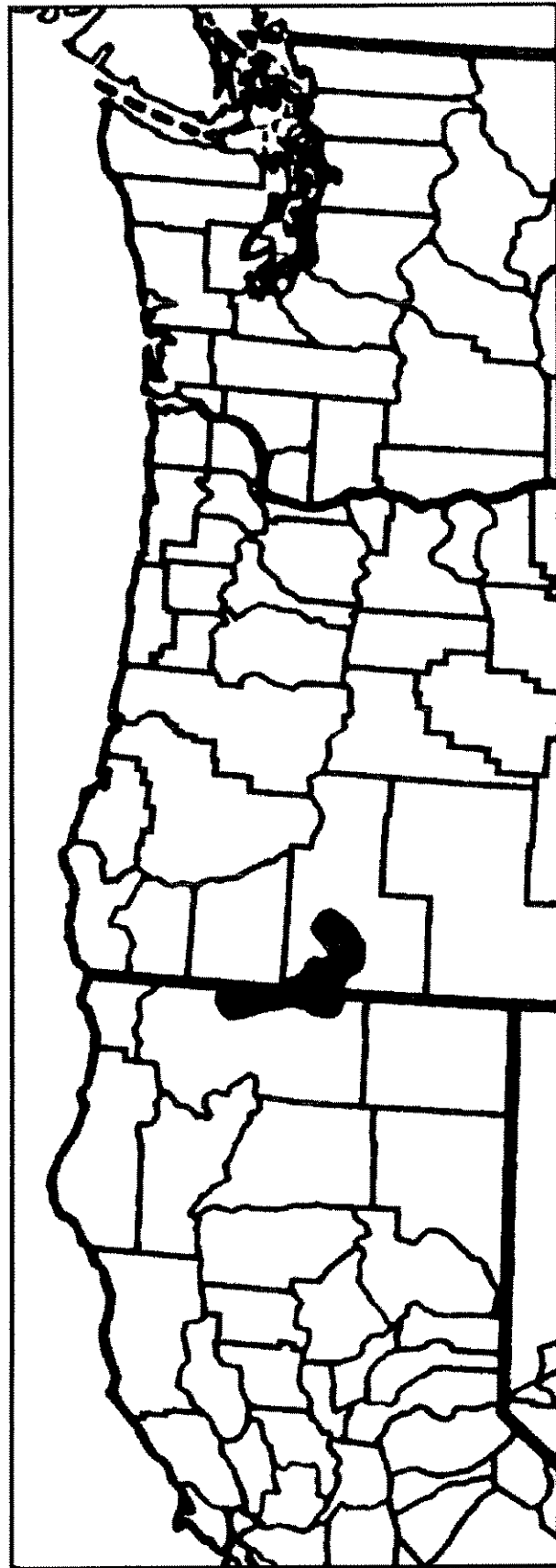


Figure 4. *Fluminicola* n. sp. 1:  
actual height 8.6 mm.



Map 1. Distribution of *Fluminicola* n.  
sp. 1.

*Fluminicola* n. sp. 2

[*Fluminicola* n. sp. 2 Frest & Johannes, in press]

tall pebblesnail

---

## DESCRIPTION

See Frest & Johannes (1995b; 1996b; 1998a, in press) for description: see also **Key 1** and **Figures 5 & 6**. Conch tall, conical, of moderate size (about 3.6-5.0 mm adult height; 2.7-3.1 mm adult width; H/W ratio ca. 1.32; decollate adults usually have ca. 2.0-2.5 whorls), but adults invariably decollate; young (to 1.5 mm height) specimens with at least 3.5 whorls, suggesting that non-decollate adults would have ca. 6-7 whorls; shell moderately thick, white; periostracum color deep green; ornament of very faint, irregular growth lines and slightly more distinct spiral lines most distinct on upper two-thirds of last two whorls; protoconch generally with about 1.5 whorls; diameter ca. 0.38 mm; almost flat, moderate-sized compared to rest of shell; rest of shell consistently spirally coiled; whorls are moderately convex; suture strongly impressed; periphery moderately well-rounded, central until last whorl, where commonly displaced slightly below midpoint; aperture rounded, slightly angled above and flattened basally; peristome barely complete; outer and basal lip thin, not noticeably reinforced; parietal lip complete across pariety; reinforced slightly; columellar shelf present, although rather narrow, barely continuing onto base; columellar ridge fairly prominent, complete to base of columella, continuing into umbilicus, columellar furrow wider than columellar shelf; umbilicus very small but open; body, tentacles, and visceral coil all appear completely black; penis flanged (has a wing-like extension toward the midpoint on the left side) and unpigmented (white).

## DISCUSSION

Most of the other taxa with a flanged verge are larger and more or less globose in shape. This taxon is perhaps the tallest *Fluminicola* yet found, somewhat resembling many species of *Pyrgulopsis* in spire shape as seen in young specimens. The closest species in shell shape is *Fluminicola modoci* from the Goose Lake area, Oregon-California. That species is smaller; has a very narrow columellar furrow; has more convex whorls; and has a more oval, inclined aperture (Hershler & Frest, 1996, Figures 4F, 5H-J). The anatomy, in particular that of the penis (*op. cit.*, Figure 9D), is also very different: see Hershler & Frest (1996) for full description. The distinctive penis of this and several other Upper Klamath Lake drainage taxa may merit separation eventually as a genus.

Hydrobiids typically are not decollate (Hershler & Ponder, 1998); but so far all adults of this taxon seem to be. The spring in which this taxon is found is if anything more alkaline than typical regionally; and accompanying *Lyogyrus* have complete adult spires. The only other taxa yet known that typically have an eroded spire (or is decollate?) are *Fluminicola modoci* (see Hershler & Frest, 1996) and the Fall Creek pebblesnail. Both taxa may just have exceptionally easily eroded spires; but note that *F. modoci* is accompanied at some sites by a second taxon whose spire is not eroded, and most Jenny Creek-Fall Creek taxa, often sympatric with the Fall Creek pebblesnail, are not decollate (Frest & Johannes, pers. obs.); this could also indicate that decollation is real. **Decollation** (defined as the controlled ability to lose the early whorls and seal the shell summit with secondary deposits) is not known with certainty to occur in hydrobiids (Hershler & Ponder, 1998). A few species of Great Basin *Pyrgulopsis* also typically have eroded spires or decollate shells (e.g., *P. planulata*, *P. sulcata*: Hershler, 1998).

This taxon was cited identically in Frest & Johannes (1993c, 1995a, b, 1996a, b, 1998a, in press).

## ECOLOGY

Confined to large undisturbed, very cold oligotrophic springs draining into Upper Klamath Lake, Klamath County, Oregon. The species occurs on pebbles and cobbles and is a perolithon grazer. Few macrophytes are present, except for local *Veronica*. Most striking at one site are large numbers of *Nostoc pruniforme*, which in some areas covers the substrate like cobbles. A crenophile, and perhaps limnocrene only, species. A perolithon grazer and lithophile. Other mollusks at one site include "*Lyogyrus*", *Lanx klamathensis*, and *Vorticifex effusa effusa*.

## ORIGINAL DISTRIBUTION

Likely restricted to larger springs tributary to Upper Klamath Lake and related drainages, California-Oregon (especially Klamath County, Oregon).

## CURRENT DISTRIBUTION

Known from a few sites, on private land adjacent to Winema National Forest, on nearby Upper Klamath Lake National Wildlife Refuge, and on Winema National Forest lands (**Map 2**; for detailed map, see Frest & Johannes (1998a, map D3)).

## REFERENCES

Frest & Johannes (1993c; 1995a, b; 1996a, b; 1998a; in press); ROD (1994); Deixis collections, 1991-1997.



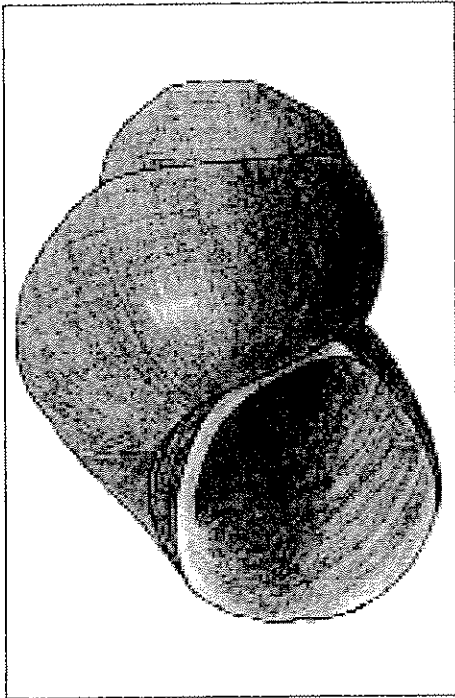
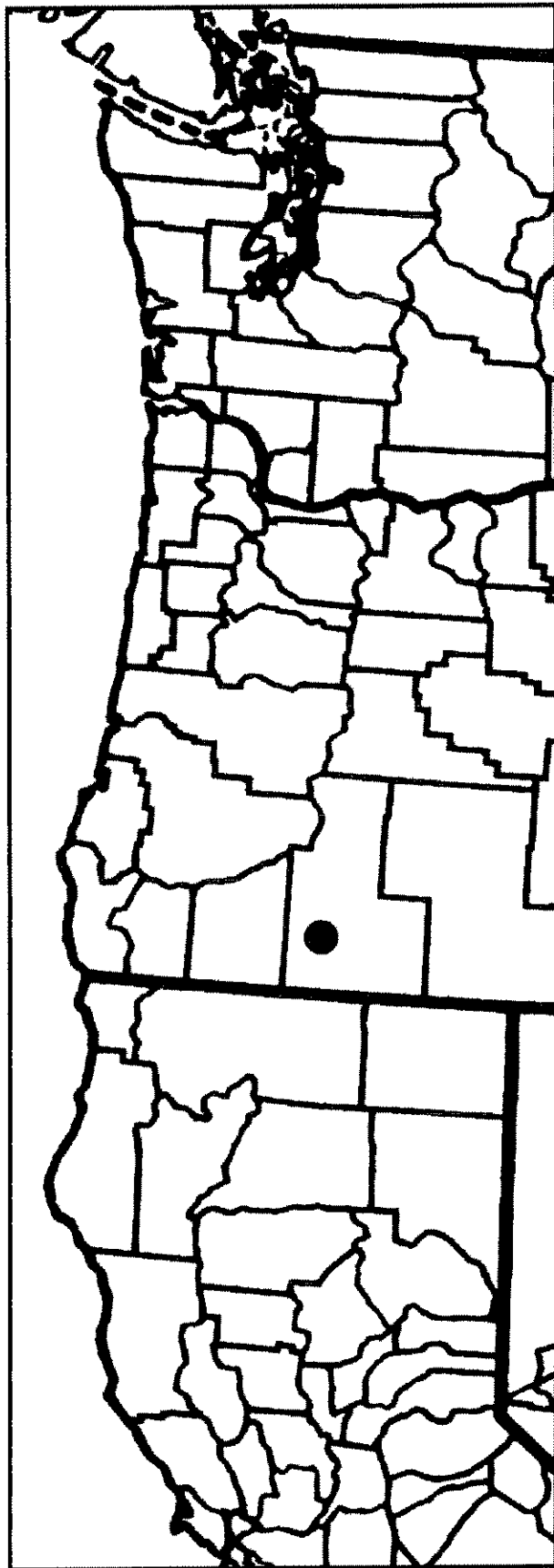


Figure 5. *Fluminicola* n. sp. 2:  
actual height 3.6 mm.



Figure 6. *Fluminicola* n. sp. 2:  
actual height 3.6 mm.



Map 2. Distribution of *Fluminicola* n.  
sp. 2.



## *Fluminicola* n. sp. 3

[*Fluminicola* n. sp. 3 Frest & Johannes, in press]

### Klamath Rim pebblesnail

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#### DESCRIPTION

See Frest & Johannes (1995b, 1996a, 1998a, in press); **Key 1**; and **Figures 7 & 8**. Conch low conical to subturbinate, small for genus (2.1-2.4 mm height; width 1.8-2.0 mm; H/W ratio ca. 1.20); height and width nearly equal; whorls generally 3.4-3.7; apex flat, protoconch of 1.5 whorls, prominent, diameter about 0.32 mm; rest of shell consistently coiled; shell semitransparent, moderately thick for size; periostracum thin, clear greenish-yellow on later teleoconch, apex usually white; ornament consists of indistinct collabral growth lines and slightly more distinct very narrow, low spiral microribs, most distinct near whorl midpoint; whorls well-rounded, convex; suture deeply impressed; whorl periphery at midpoint until last half whorl, where displaced slightly below midpoint; aperture barely adnate, in contact with preceding whorls mostly at apex of pariety; well-shouldered above, deep suture; aperture triangular-ovate, definitely angled above, evenly rounded below, large (height to 0.6 shell height); columellar shelf thin but distinct, continues evenly across whole of parietal wall; outer and basal lip thin; columellar furrow broadly lunate, originating slightly above base of columellar wall and disappearing into umbilicus; columellar ridge distinct; grooves distinct; complex well excavated, almost twice as wide maximally as columellar shelf; umbilicus distinctly open, width ca. 0.3 mm. Body light grey; tentacles and snout only slightly darker, if at all; visceral coil also light-medium grey; penis narrow, elongate, sickle-shaped, unpigmented.

Distinctive features of this taxon are the small size (height under 2.5 mm), rather evenly gray body and tentacles, and narrow, elongate, sickle-shaped penis. Coiling is normal in this taxon; and the shell is average in thickness, as contrasted with the diminutive pebblesnail (*q.v.*).

#### DISCUSSION

Only a few *Fluminicola* taxa are this small as adults. In this area, the diminutive pebblesnail (*Fluminicola* n. sp. 12; see **Key 2**) is somewhat similar; but that taxon has a thick, squat shell and the last whorl is noticeably deflected. *Fluminicola* n. sp. 3 was cited under the same name in Frest & Johannes (1993c; 1995a, b; 1996a, b; 1998a).

## ECOLOGY

Small cold spring run; very shallow water; gravel-cobble substrate; no macrophytes present. The snail occurs only in shaded areas and may be photophobic. A perolithon grazer and lithophile.

## ORIGINAL DISTRIBUTION

Uncertain; likely restricted to the middle portion of the Klamath drainage, *i.e.*, below Upper Klamath Lake and above Copco Reservoir; Klamath County, Oregon and Siskiyou County, California.

## CURRENT DISTRIBUTION

Single site in Klamath County, Oregon, on Lakeview District BLM lands (**Map 3**; for detailed map, see Frest & Johannes (1998a, map D3)). The area is currently badly grazed; adjacent springs do not have this species. We are currently engaged in a comprehensive survey of Upper Klamath Lake freshwater mollusks (see Frest & Johannes, 1998a); it is unlikely that future work will expand the geographic range and number of sites sufficiently as to militate against special concern for this taxon.

## REFERENCES

Frest & Johannes (1993c; 1995a, b; 1996a, b, 1998a, in press); ROD (1994); Deixis collections, 1991.

Key 2. Middle Klamath (Jenny Creek-Fall Creek) *Fluminicola* species  
[Survey & Manage: *Fluminicola* n. sp. 11]

At present, about 7 taxa of this genus are known from the Jenny Creek-Fall Creek area. Note that further exploration may modify this number; and that some adjacent drainages (e.g., Johnson Creek; Keene Creek) also have *Fluminicola*. Only one of these taxa is included here. Consultation with a specialist is very helpful in identifying taxa from this region; and soft part criteria are also very important.

- 1 Adult shell under 1.5 mm in length; shell thick, subglobose; aperture heavily reinforced; last 1/4 whorl deflected .....  
..... *Fluminicola* n. sp. 12 Frest & Johannes, in press  
Adult shell > 1.7 mm in length ..... 2
- 2 Adult shell subconic ..... 3  
Adult shell neritiform; strongly reinforced apertural margin; few whorls; strong columellar furrow .....  
..... *Fluminicola* n. sp. 10 Frest & Johannes, in press
- 3 Shell yellow in color; often with brown coating; last whorl and aperture disjunct; aperture reinforced all around, lunate; body pigment lacking .....  
..... *Fluminicola* n. sp. 15 Frest & Johannes, in press  
Shell green or greenish-yellow ..... 4
- 4 Shell greenish-yellow; subconic ..... 5  
Shell green ..... 6
- 5 Aperture with thin margin all around; length 3 mm; whorls moderately convex .....  
..... *Fluminicola* n. sp. 13 Frest & Johannes, in press  
Aperture with somewhat thickened margin all around; length 2 mm; whorls slightly flattened ..... *Fluminicola*  
n. sp. 11 [*Fluminicola* n. sp. 17 Frest & Johannes, in press]
- 6 Shell normally coiled; aperture simple (lacking nodes or lamellae) ..... 7  
Last 1/2-1 whorl disjunct, deflected downward; aperture reinforced all around; single strong columellar node .....  
..... *Fluminicola* n. sp. 11 Frest & Johannes, in press
- 7 Shell low trochoid-subglobose, to 4 mm height; dark green; aperture slightly reinforced all around, more heavily along columella ..... *Fluminicola* n. sp. 16 Frest & Johannes, in press  
Shell low conic, to 3.5 mm height; apple green; aperture slightly reinforced all around .....  
..... *Fluminicola* n. sp. 14 Frest & Johannes, in press

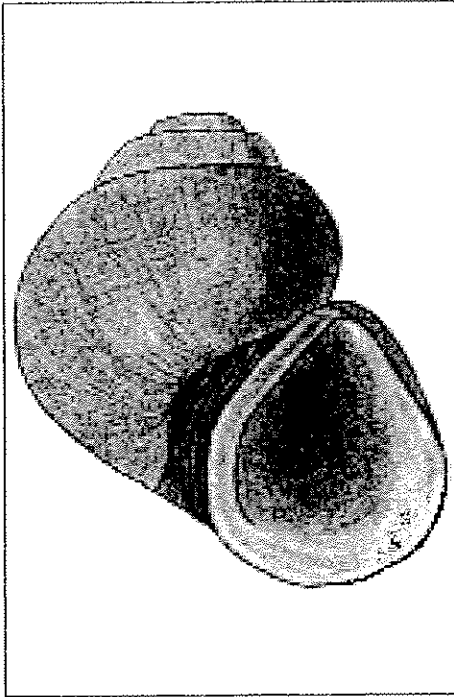


Figure 7. *Fluminicola* n. sp. 3:  
actual height 2.4 mm.

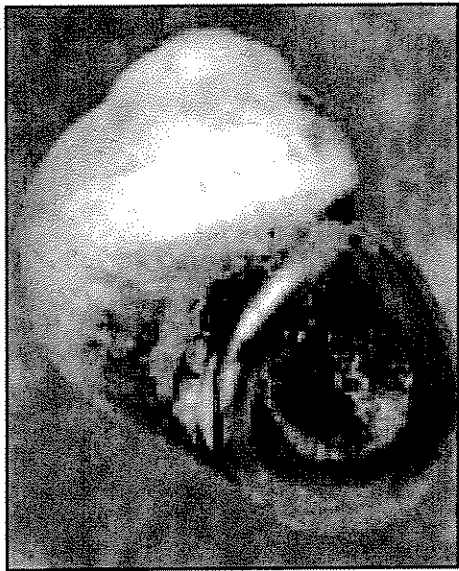
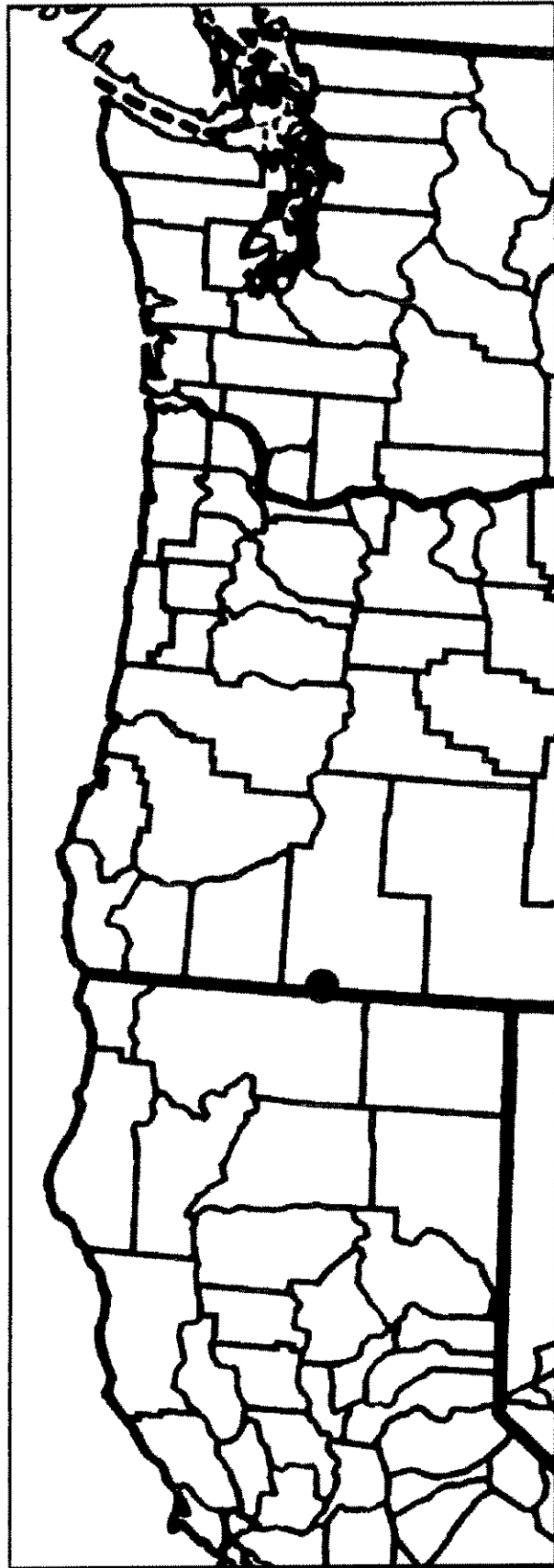


Figure 8. *Fluminicola* n. sp. 3:  
actual height 2.7 mm.



Map 3. Distribution of *Fluminicola* n.  
sp. 3.

*Fluminicola* n. sp. 11

[*Fluminicola* n. sp. 17 Frest & Johannes, in press]

## Fredenburg pebblesnail

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### DESCRIPTION

See Frest & Johannes (1993c, 1998a, 1999, in press); Key 2; and Figures 9 & 10. Conch low conical-subturbinate, small to medium-sized for genus (3.0-3.3 mm height; width 2.4-2.8 mm; H/W ratio ca. 1.19); height slightly exceeding width; whorls generally 3.3-3.8; shell apex flat, protoconch of 1.5 whorls, prominent, diameter about 0.46 mm; rest of spire consistently coiled; shell opaque, white, solid, thick for size; periostracum thin, greenish-yellow; ornament consists of indistinct collabral growth lines, with every 4th-5th more distinct; spiral striation seemingly absent; whorls well-rounded, convex; suture deeply impressed; whorl periphery at midpoint; aperture broadly in contact with preceding whorl; shouldered above, deep suture; aperture subcircular-ovate, angled above, evenly rounded below, comparatively large (height to 0.57 shell height); columellar shelf moderate in thickness, shelf continues, thinning slightly, across whole of parietal wall; most of outer lip also distinctly thickened, only part of basal lip thin; columellar furrow small, originating at base of columella as very thin strip, widening abruptly near top of columella into small, lunate area and continuing into umbilicus; columellar ridge indistinct; grooves few, closely spaced; columellar furrow only slightly excavated, much narrower than columellar shelf; umbilicus very small, width ca. 0.15 mm; generally shell appears anomphalous. Body light grey; tentacles and snout only slightly darker, if at all; visceral coil also light-medium grey; penis narrow, elongate, sickle-shaped, unpigmented.

Distinctive features of this taxon are the small size (height under 3.3 mm), rather evenly gray body and tentacles, and narrow, elongate, sickle-shaped penis. Coiling is normal in the Fredenburg pebblesnail; and the shell is average in thickness, as contrasted with the diminutive pebblesnail (*q.v.*).

### DISCUSSION

This species has somewhat generalized morphology that is mostly notable for its lack of specialized features. Growth lines in this taxon are more than usually prominent; but not regular enough to constitute collabral lirae. Other taxa of similar shell appearance but different anatomy occur in the Upper Sacramento and Upper Klamath Lake drainage systems. For key to Jenny Creek-Fall Creek area *Fluminicola* species, including this one, see Key 2.

Cited as *Fluminicola* n. sp. 11 in Frest & Johannes (1993c, 1996a); and as *Fluminicola* n. sp. 17 in Frest & Johannes (1999, in press).

## **ECOLOGY**

Occurs in narrow and shallow small cold spring runs, on cobbles and gravel. Associated with *Mimulus* and *Rorippa*. Appears to be an obligate crenocole.

## **ORIGINAL DISTRIBUTION**

Uncertain; likely a narrow endemic confined largely to a few spring runs tributary to the middle Klamath drainage, Jackson County, Oregon.

## **CURRENT DISTRIBUTION**

Found at several sites in and flanking the Jenny Creek drainage, southeastern Jackson County (**Map 4**); many other springs in the surrounding area have been completely trampled out by grazing cattle. One or two sites may be on private lands; others are on lands included in Medford District BLM holdings.

## **REFERENCES**

Frest & Johannes (1993c; 1996a; 1999; in press); ROD (1994); Deixis collections, 1991-1996, 1998.

Key 3. Upper Sacramento-Pit River *Fluminicola* Species  
[Survey & Manage: *Fluminicola* n. sp. 14-20, *Fluminicola seminalis*  
(Hinds, 1842)]

About 15 *Fluminicola* (s.l.) species are currently known from the Upper Sacramento and Pit river drainage, CA. All appear to be endemic to the Sacramento Basin and all but *seminalis* are undescribed. A few others are likely to be discovered. For more information on currently known Upper Sacramento drainage species, see Frest & Johannes (1995c, 1997, in press). These taxa are best discriminated using anatomic criteria; but shell characters can be used also. For example of more complete description of *Fluminicola* (s.l.), see Hershler & Frest (1996). Western US material belonging to the Lithoglyphinae, with the possible exception of the taxa covered in Hershler & Frest (1996), should be relaxed and preserved and examined by specialists. Consultation with a specialist may be important for small members of the genus, such as most of these taxa, especially in regions with several sympatric species. *Fluminicola* is a large and difficult genus (or soon will be), and we do not recommend identification of material from shells alone found in areas in which similar species are known or likely to occur.

This key does not cover all known species; but should eliminate the non-Survey & Manage taxa and allow tentative identification of Upper Sacramento drainage Survey & Manage taxa. **Identification of extralimital taxa, even in immediately adjacent drainages, should not be attempted using this key; and anticipated addition of other species will require its modification** (for example, see middle Klamath and Upper Klamath Lake drainage keys above). Because various number schemes have been applied to the undescribed taxa, only those used for the ROD (1994) report are used here [n. sp. 14-20: in bold text here]; the remaining taxa are used as in Frest & Johannes (1995c, 1997, in press).

- 1 Shell comparatively large, over 1 cm in height .....  
..... *Fluminicola seminalis* (Hinds, 1842)  
Shell comparatively small, generally < 7 mm height ..... 2
- 2 Shell broadly conic [*sensu* Burch 1989, fig. 5c] ..... 3  
Shell globosely conic [Burch, 1989, fig. 5c] to globose [Burch,  
1989, fig. 4c] ..... 7
- 3 Shell very small, less than 3 mm height ..... 4  
Shell larger, 3-7 mm in height ..... 5

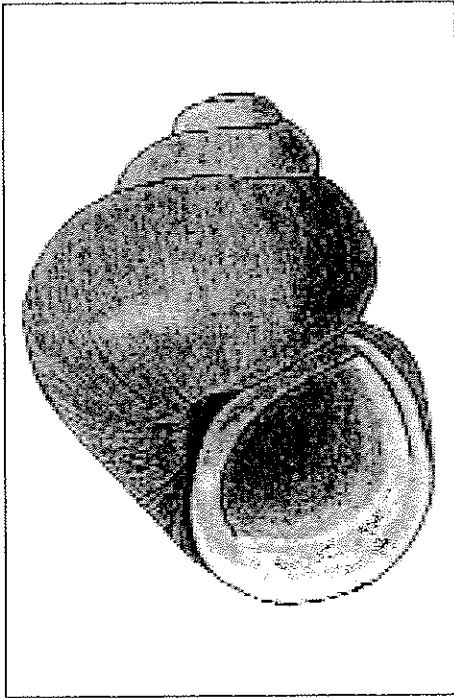


Figure 9. *Fluminicola* n. sp. 11:  
actual height 3.1 mm.

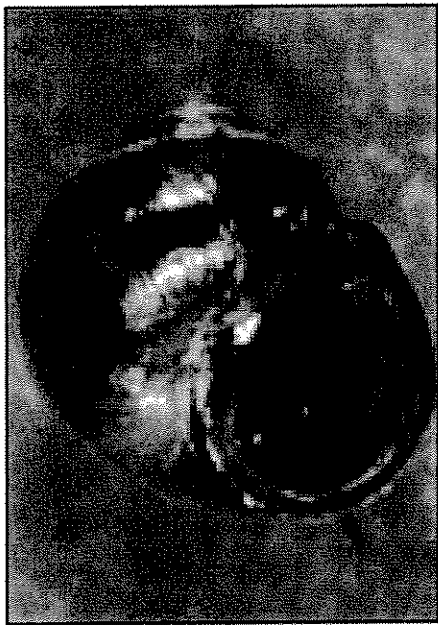
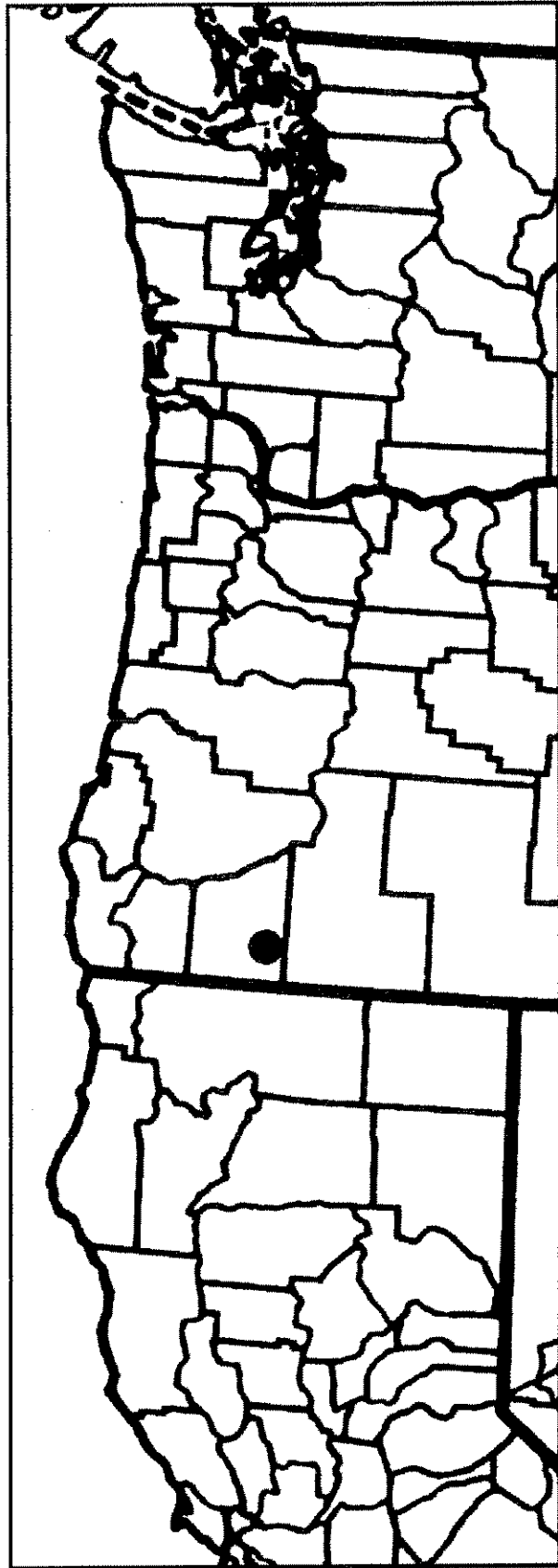


Figure 10. *Fluminicola* n. sp.  
11: actual height 3.0 mm.



Map 4. Distribution of *Fluminicola* n.  
sp. 11.



4 Shell greenish, 3.5-4.0 whorls, protoconch almost flat, small  
..... *Fluminicola* n. sp. 38 Frest & Johannes, in press  
Shell yellowish, 3.0 whorls, large flat protoconch .....  
..... *Fluminicola* n. sp. 15 [*Fluminicola* n. sp. 21 Frest &  
Johannes, in press]

5 Shell comparatively large (to 5 mm height); last 1/2 whorl  
deflected .....  
..... *Fluminicola* n. sp. 19 Frest & Johannes, in press  
Shell smaller (3-4 mm); last whorl normally coiled ..... 6

6 Aperture evenly but slightly callused all around .....  
..... *Fluminicola* n. sp. 14 [*Fluminicola* n. sp. 20 Frest &  
Johannes, in press]  
Aperture callused all around but basally obviously thickened .....  
..... *Fluminicola* n. sp. 16 [*Fluminicola* n. sp.  
22 Frest & Johannes, in press]

7 Shell globosely conic ..... 8  
Shell globose or subglobose ..... 11

8 Last whorl disjunct ..... *Fluminicola* n. sp. 17  
[*Fluminicola* n. sp. 23 Frest & Johannes, in press]  
Last whorl normally coiled ..... 9

9 Shell imperforate .....  
..... *Fluminicola* n. sp. 39 Frest & Johannes, in press  
Shell umbilicate ..... 10

10 Umbilicus 1/5 shell diameter; columellar complex relatively large;  
whorls somewhat flattened .....  
..... *Fluminicola* n. sp. 20  
[*Fluminicola* n. sp. 26 Frest & Johannes, in press]  
Umbilicus 1/3-1/4 shell diameter; whorls strongly convex;  
columellar complex small ..... *Fluminicola* n. sp. 19  
[*Fluminicola* n.sp. 25 Frest & Johannes, in press]

11 Shell yellowish; body unpigmented or barely pigmented ..... 12  
Shell green; body pigmented, eye spots lighter ..... 13

- 12 Aperture reinforced slightly around whole periphery; body pigmentless, eye spots dark, large; umbilicus perforate (Burch, .... 1989, fig. 6d); size about 4 mm ..... *Fluminicola* n. sp. 18 [*Fluminicola* n. sp. 24 Frest & Johannes, in press]  
Aperture reinforced slightly around whole periphery; body lightly pigmented, eye spots dark, small; umbilicus distinctly open; size about 6 mm ..... *Fluminicola* n. sp. 40 Frest & Johannes, in press
- 13 Whorls convex, relatively rapidly expanding (not neritiform) ..... *Fluminicola* n. sp. 25 Frest & Johannes, in press  
Shell neritiform ..... 14
- 14 Final 1/2 whorl disjunct; paucispiral operculum ..... *Fluminicola* n. sp. 37 Frest & Johannes, in press  
Final whorl normally coiled; multispiral operculum ..... *Fluminicola* n. sp. 36 Frest & Johannes, in press

*Fluminicola* n. sp. 14

[*Fluminicola* n. sp. 20 Frest & Johannes, in press]

## Potem pebblesnail

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### DESCRIPTION

Conch with medium high conic spire (rounded at apex): small to medium-sized for genus; most adults *ca.* 3.8-4.4 mm in height, rarely ranging to about 5.0 mm; width typically 3.1-3.5 mm; H/W ratio approximately 1.24; adults have about 4.25-4.50 whorls (**Figures 11 & 12**). Shell thick and white (opaque) on long-preserved material; semi-transparent when live, periostracum thin, dark, slightly olive green; faint collabral growth lines, somewhat irregular; and (rarely) spiral, almost undistinguishable spiral scratches; protoconch comparatively small and flattened, *ca.* 0.47 mm width; shell apex blunt; later whorls evenly coiled and moderately strongly convex; suture deeply impressed; whorl periphery widest at midpoint. Aperture ovate, bluntly angled above; large, height about 0.56 of full shell height; entire margin thickened more or less evenly (except possibly the base), but columellar shelf narrow compared to other taxa; aperture in contact with parietal wall across entire length; in mature specimens, periostracum and thin underlying outer edge slightly advanced over rest of lip in parietal area. Columellar furrow narrow, shallow, lunate, beginning at about columellar lip midpoint, ending in very small umbilicus, columellar ridge not prominent, few columellar grooves; umbilicus usually barely open, but shell commonly appearing anomphalous. Visceral coil dark gray to black; tentacles and snout dark gray-black above, lighter below; foot light gray; anterior and posterior corners of foot darker; penis medium length for genus, gently curved blade, unpigmented; seldom seen in this taxon. Operculum very light amber.

The most distinctive shell features of this species are the evenly reinforced aperture and rather narrow columellar furrow.

### DISCUSSION

The Potem pebblesnail is a rather generalized form without much in the way of exaggerated shell or exterior anatomical features. It is most easily confused with two taxa, *Fluminicola* n. sp. 38 and *Fluminicola* n. sp. 22 (Survey & Manage *Fluminicola* n. sp. 16). *Fluminicola* n. sp. 38 is always smaller, even when mature; the shell appears slightly thinner overall; and the apex appears almost flat, rather than domed as in this taxon. Survey & Manage *Fluminicola* n. sp. 16 (*Fluminicola* n. sp. 22) is closely similar in size and general appearance; but that taxon has a

basal apertural lip that is distinctly thicker than is the case here. Note also that Survey & Manage *Fluminicola* n. sp. 14 (*Fluminicola* n. sp. 20) tends to occur in smaller springs than does ROD *Fluminicola* n. sp. 16 (*Fluminicola* n. sp. 22). For comparisons with other Upper Sacramento-Pit river drainage *Fluminicola* species, see **Key 3**. This is a Survey & Manage species under the name *Fluminicola* n. sp. 14 (same as in Frest & Johannes, 1993c, 1996a); previous usages were *Fluminicola* n. sp. 2 in Frest & Johannes (1993d, 1994, 1995c, 1997; and *Fluminicola* n. sp. 20 in Frest & Johannes (in press): see also Table 6 in Frest & Johannes (in press).

## ECOLOGY

Occurs on muddy-silty substrate in small cold springs and spring runs. Sites are often shaded; the species appears to graze on partly decayed deciduous leaves. May occur with other endemic *Fluminicola* spp. This species appears to be restricted to small cold springs. Most sites are small and shallow but perennial cold spring runs with silt substrate; this crenophile species could be a detritivore as well as a grazer.

## ORIGINAL DISTRIBUTION

Upper Sacramento River and Pit River tributaries in Shasta County, California.

## CURRENT DISTRIBUTION

Eleven sites at present (**Map 5**); for detailed map, see Frest & Johannes (1995c, map D15). Known localities are on private lands (one may be within Shasta National Forest); we anticipate that additional sites in Shasta National Forest, Whiskeytown-Shasta-Trinity National Recreation Area, and areas administered by Lassen National Forest will be found, as some existing sites have federal lands immediately adjacent or are surrounded by such lands. One site is close to DCA [Designated Conservation Area] CD-83; another appears to be on Shasta National Forest property. Management of nearby DCAs CD-64, 65, 66, 67, & 68 will likely impact this species in part of its range. It is likely to be found on some of the listed DCAs.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1991-1997.

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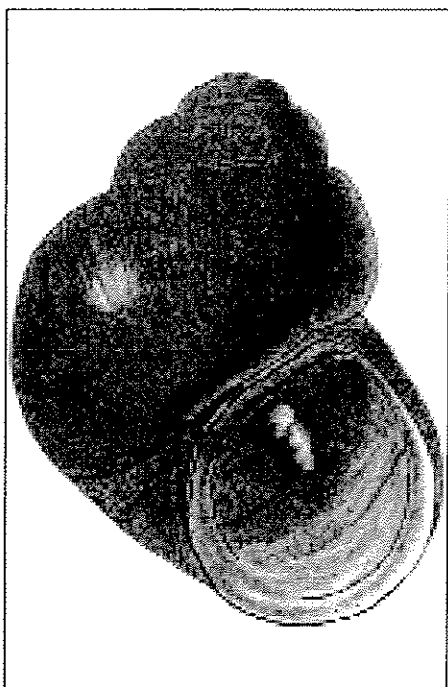
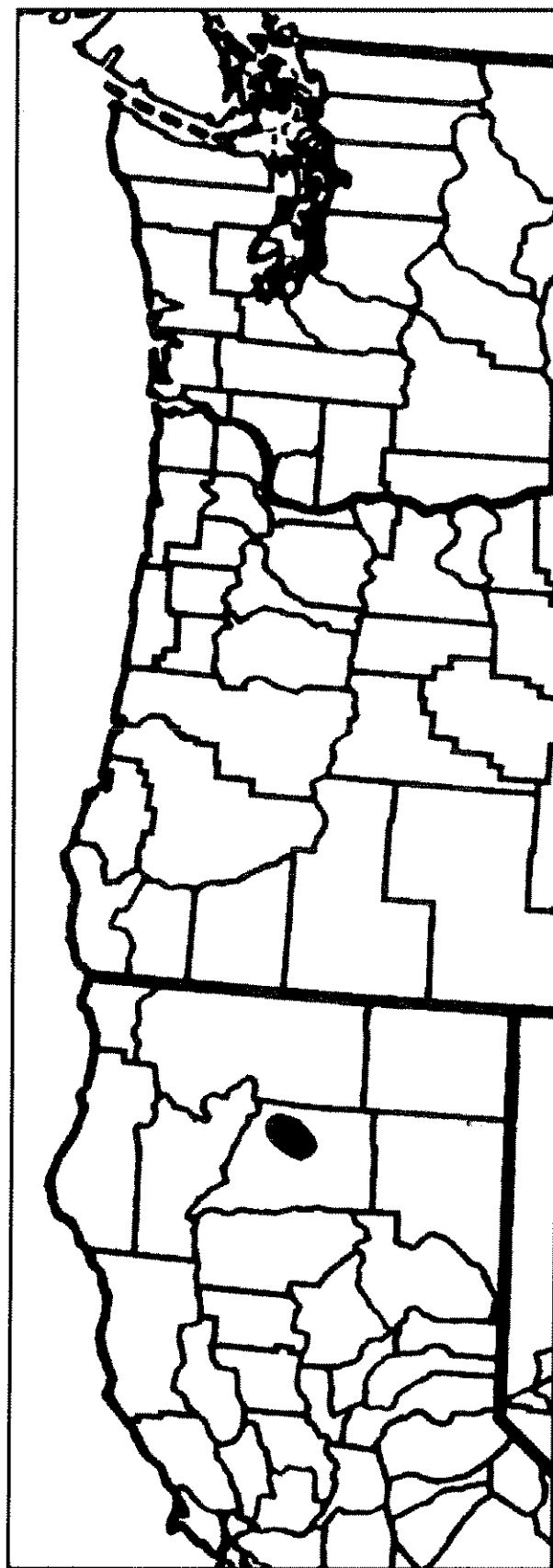


Figure 11. *Fluminicola* n. sp.  
14: actual height 4.1 mm.



Figure 12. *Fluminicola* n. sp.  
14: actual height 4.0 mm.



Map 5. Distribution of *Fluminicola* n.  
sp. 14.

*Fluminicola* n. sp. 15

[*Fluminicola* n. sp. 21 Frest & Johannes, in press]

flat-top pebblesnail

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## DESCRIPTION

Conch small (height commonly ca. 2.5 mm but ranging to 2.9 mm; width ca. 2.0-2.3 mm; H/W ratio about 1.32: **Figures 13 & 14**), with rather tall conic spire with somewhat flattened (barely convex until ultimate whorl) adult whorls (about 3.75-4.25 whorls in adults) and surmounted by large, flat protoconch (width ca. 0.70 mm). Shell comparatively thin, translucent and clear; periostracum very thin, yellow; growth lines very faint except on final whorl. Early whorls distinctly shouldered above; but ultimate whorl well-rounded, with periphery at midpoint. Aperture ovate-circular, bluntly angled above; height ca. one-half full shell height (about 0.53); columellar shelf moderately thick, expanding barely onto basal lip, thinning onto parietal abruptly at mid-point, merely a glaze on upper third of parietal wall (parietal callus incomplete); remainder of lip margin very thin. Umbilicus very narrow but consistently present (perforate); no, or just a trace of, a shallow columellar furrow located high on columellar margin and always incomplete below, with distinguishable weak columellar ridge but grooves not separable. Body almost colorless except for eye spots, cephalic tentacles and distal snout light gray above; visceral coil similarly pigmentless or very light gray; penis seldom well-relaxed in this taxon; medium-sized, pigmentless, sickle-shape, somewhat narrow. Operculum yellow.

## DISCUSSION

Unusual features of this taxon are the nearly pigmentless body; rather flat-sided early whorls; and disproportionately large, flat protoconch. All *Fluminicola* (s.l.) have a rather flattened protoconch, commonly giving the spire a slightly domed appearance; but this taxon seems unusually planar at the apex, in part owing to the rather flattened succeeding whorls. This morphology is fairly unique among the known taxa. For key to Upper Sacramento-Pit area *Fluminicola* species, see **Key 3**. This is a Survey & Manage taxon under the Frest & Johannes (1993c, 1996a) appellation *Fluminicola* n. sp. 15: otherwise termed *Fluminicola* n. sp. 3 in Frest & Johannes (1993d, 1994, 1995c, 1997) and *Fluminicola* n. sp. 21 in Frest & Johannes (in press): see also Table 6 in Frest & Johannes (in press).

## ECOLOGY

Confined to small cold springs and spring sources; substrate ranges from sand to gravel (mostly gravel). *Fluminicola* n. sp. 15 is a crenophile, occurring in small but perennial cold springs or at spring sources, mostly on gravel substrate. It appears to be a perolithon grazer. May be associated with other endemic *Fluminicola* spp. or with *Juga* (*Oreobasis*) n. sp. 3. A couple of springs with this taxon have abundant macrophytes, such as *Rorippa* and *Mimulus*; but it is not clear that these are necessary, as other sites have almost no larger water plants. Appears to be a perolithon feeder, like most small species.

## ORIGINAL DISTRIBUTION

Upper Sacramento River and Pit River drainages, Shasta County, California.

## CURRENT DISTRIBUTION

The species so far is an Upper Sacramento system endemic, known from 4 sites in the upper Sacramento drainage in Shasta County, California (**Map 6**; for more detailed map, see Frest & Johannes (1995c, map D16)). Known sites are on private lands, in some cases interspersed with extensive federal holdings; but most suitable habitat is in Shasta National Forest, areas administered by Lassen National Forest, and Whiskeytown-Shasta-Trinity National Recreation Area. Management of nearby DCAs CD-64, 65, 66, 67, & 68 will likely impact this species in some areas.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1992, 1997.





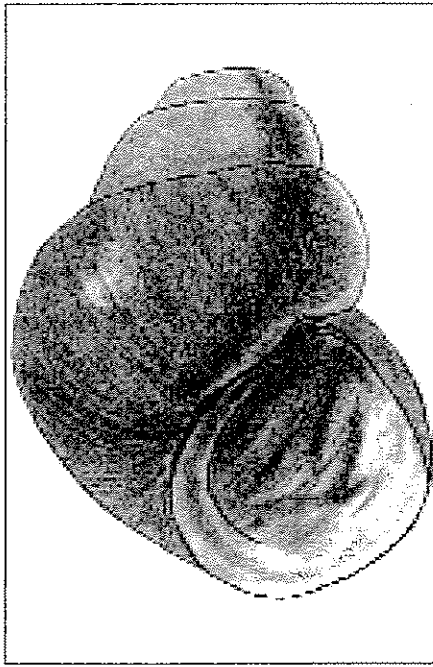
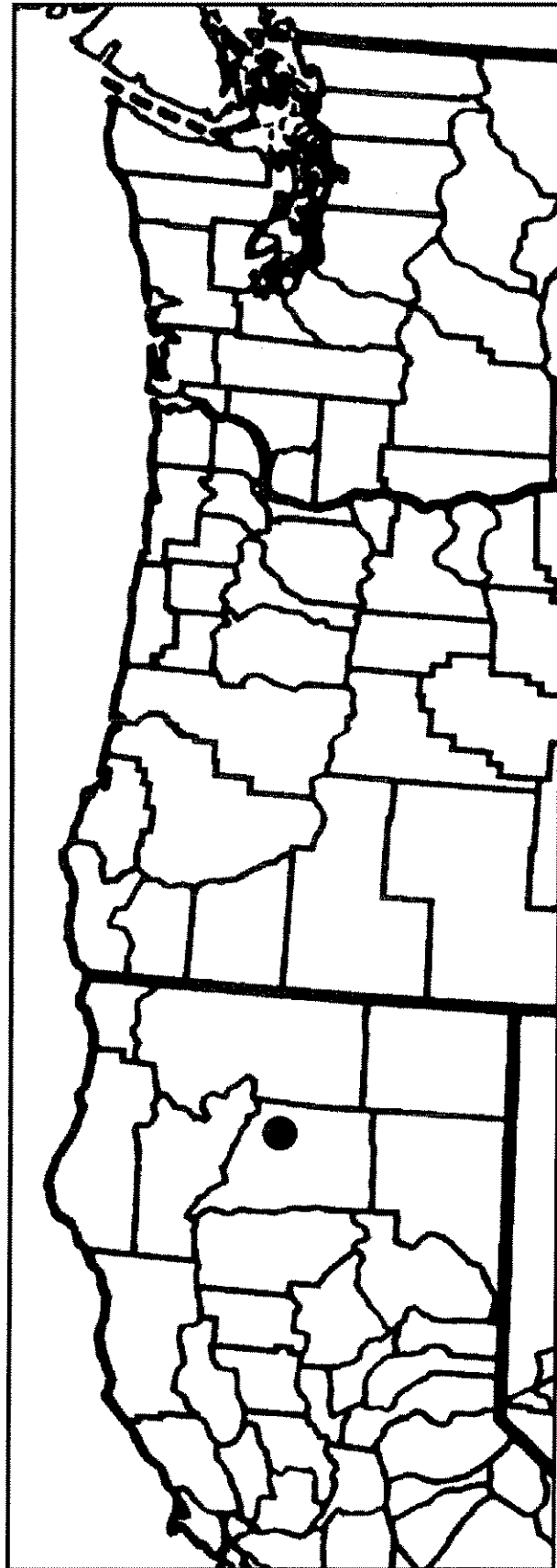


Figure 13. *Fluminicola* n. sp.  
15: actual height 2.9 mm.



Figure 14. *Fluminicola* n. sp.  
15: actual height 2.7 mm.



Map 6. Distribution of *Fluminicola* n.  
sp. 15.

*Fluminicola* n. sp. 16

[*Fluminicola* n. sp. 22 Frest & Johannes, in press]

## Shasta Springs pebblesnail

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### DESCRIPTION

Conch small to medium-sized for genus, with low conic spire (Figures 15 & 16): adult height about 3.5-4.3 mm; width 3.0-3.6 mm; H/W ratio 1.19; ca. 3.75-4.25 whorls; large, blunt protoconch with 1.5 whorls, width ca. 0.57 mm; adult whorls even, moderately convex, periphery widest at center (midpoint) of whorl; suture moderately impressed. Shell white, opaque, moderately thick; periostracum medium to dark green; growth lines fine, mostly indistinct except patchily on last whorl; distinct though quite narrow (less than one-third width of columellar shelf, elongate lunate columellar furrow not reaching the base of the columella; columellar ridge distinct; columellar grooves fine, numerous; complex terminates at umbilicus; umbilicus typically closed. Aperture almost round, bluntly angled above; parietal lip completely in contact with preceding whorl; aperture margin subcircular and moderately thickened almost completely around; basal lip shelf slightly wider than columellar shelf; columellar shelf moderately wide. Body light or medium gray except on foot base; tentacles darker, with tendency in most populations to darker narrow central stripe on upper surface and darker tip; distal upper snout and anterior end of foot also darker; the visceral coil is similarly colored; penis medium-sized, unpigmented epithelium, almost straight, medium thickness, blade-shaped. The operculum is dark to medium orange-brown.

### DISCUSSION

This Upper Sacramento endemic crenocole species most closely resembles *Fluminicola* n. sp. 20; but the features of the spire and aperture are distinct. As regards the latter, the basal lip is not conspicuously thicker, as it is in *Fluminicola* n. sp. 20 (Survey & Manage *Fluminicola* n. sp. 14); and the margin approaches circularity (distinctly ovate in *Fluminicola* n. sp. 20 [Survey & Manage *Fluminicola* n. sp. 14]). For comparisons with the full range of Upper Sacramento-Pit *Fluminicola*, see Key 3. Formerly (Frest & Johannes, 1993c, 1996a) termed *Fluminicola* n. sp. 16 and a Survey & Manage taxon under that name; in other works, called *Fluminicola* n. sp. 4 in Frest & Johannes (1993d, 1994, 1995c, 1997); presently (Frest & Johannes, in press) *Fluminicola* n. sp. 22. The common name was Shasta Springs pebblesnail in Frest & Johannes (1995c; termed Shasta pebblesnail in Frest & Johannes (in press).

Note the sizable number of *Fluminicola* species in this drainage. *Fluminicola* most typically has a single species at each site; but larger limnocrenes may have two; or in very exceptional cases (Jenny Creek drainage), up to 5 living sympatrically.

## ECOLOGY

Generally occurs in lower portions of larger cold springs, among *Rorippa* beds and on cobbles and pebbles. May be associated with other endemic *Fluminicola* spp. or with *Juga* (O.) n. sp. 3. Seemingly an obligate crenocole, found only in large spring complexes.

## ORIGINAL DISTRIBUTION

Probably a comparatively narrow endemic, spring-restricted form: most likely endemic to the Sacramento River drainage.

## CURRENT DISTRIBUTION

Confined to a couple of spring complexes along the upper Sacramento River, Shasta County, California, at 11 sites (**Map 7**; for detailed map, see Frest & Johannes (1995c, map D17)). Most of these are on private lands, but some are on Shasta National Forest property.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997); ROD (1994); Deixis collections, 1992-1996, 1997.



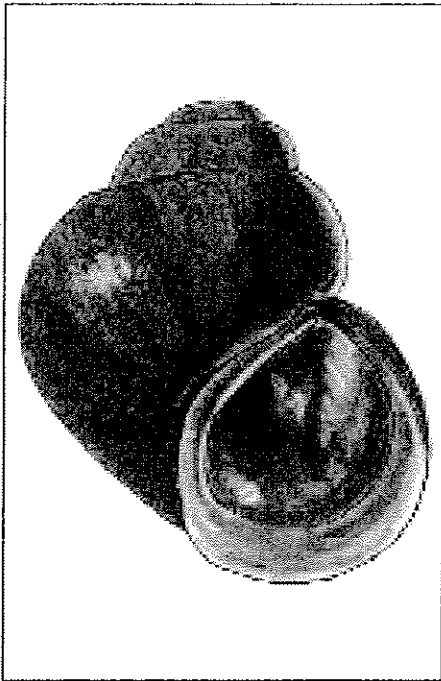
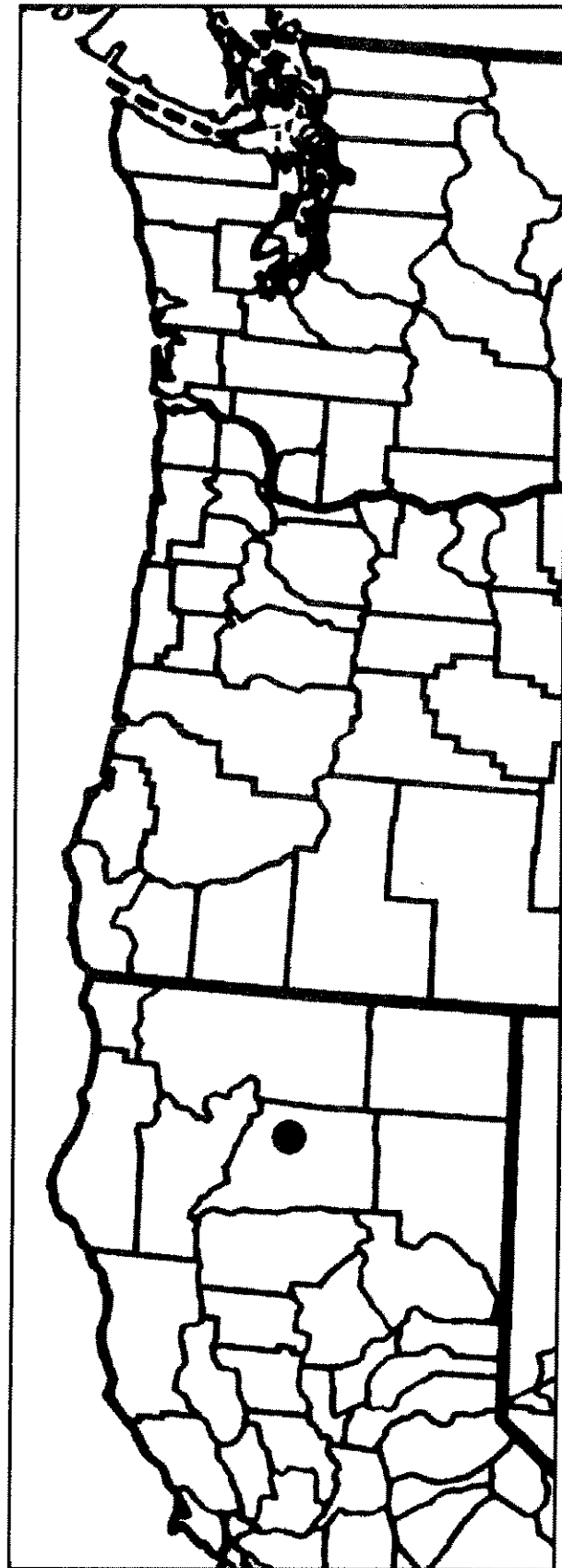


Figure 15. *Fluminicola* n. sp.  
16: actual height 4.1 mm.



Figure 16. *Fluminicola* n. sp.  
16: actual height 4.1 mm.



Map 7. Distribution of *Fluminicola* n.  
sp. 16.

*Fluminicola* n. sp. 17

[*Fluminicola* n. sp. 23 Frest & Johannes, in press]

## disjunct pebblesnail

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### DESCRIPTION

Conch effectively moderately tall conical (Figures 17 & 18); spire flattened at apex, and then normally coiled for about 1-1.5 additional whorls; but remaining 1-2 whorls slightly disjunct, and final 0.5-0.75 whorl strongly descending also; whorls 4.0-4.5; height 3.5-3.8 mm; width 2.7-3.1 mm; H/W ratio typically about 1.25. All whorls except initial 1.5 (protoconch: diameter approximately 0.60 mm) strongly convex, with periphery well-rounded and widest at midpoint; suture very deeply impressed on teleoconch whorls; early teleoconch whorls appear deeply shouldered in side and apical (top) view. Aperture circular, reinforced equally but thinly around whole margin; columellar furrow well-developed, broadly and elongately lunate at first appearance (but adapically open, abapically closed), several times wider than columellar shelf at widest point; very distinct columellar ridge begins at columellar base, is exaggerated by the disjunct coiling to become a broad band subparallel to aperture margin, gradually fades on parietal wall of aperture, extends nearly to outer lip wall; columellar grooves numerous, distinct basally then fading at top of aperture; umbilicus above disjunct whorls moderately wide, open. Aperture proportionately very large, height about 0.52 times full height despite deflected and disjunct last whorl. Shell thin, barely translucent white except at aperture (last 0.75-1.0 whorls thicker, opaque white); periostracum dark emerald green, sometimes with whitish radial streaks; collabral growth lines indistinct except for last whorl. Body dusted with gray; similarly pigmented on base of foot; tentacles and distal snout darker (on upper side only) anterior and posterior margins of foot slightly darker also; visceral coil black; penis rather stout sickle-shaped, unpigmented; operculum light horn.

This is the most spectacular of the new Upper Sacramento system *Fluminicola* species. There are no additional living species found so far which have as obviously disjunct coiling, although several species have the final 0.25-0.50 whorl slightly disjunct.

### DISCUSSION

The disjunct lower whorls and dark green (almost emerald) shell are quite distinctive. There is (or was) a similar species in the Shasta River valley, Siskiyou County, California (material in Santa Barbara Museum of Natural History, examined in 1997); but that taxon appears to be

extinct. This species is among those compared and contrasted in Key 3. A Survey & Manage taxon under the Frest & Johannes (1993c, 1996a) name *Fluminicola* n. sp. 17. Formerly called *Fluminicola* n. sp. 5 (Frest & Johannes, 1993d, 1994, 1995c, 1997) and now (Frest & Johannes, in press) *Fluminicola* n. sp. 23: see Table 6 of Frest & Johannes (in press) for history of name.

## ECOLOGY

Lower parts of larger cold springs, on *Rorippa* and large substrate particles. May be associated with other endemic *Fluminicola* spp. Like the preceding species, this taxon appears to be an obligate crenocole, found only in very large cold springs.

## ORIGINAL DISTRIBUTION

Probably a narrow endemic, restricted to the upper part of the Sacramento River drainage in Shasta County, California.

## CURRENT DISTRIBUTION

Known from three sites in a single, privately-owned spring complex (Map 8; for more detailed map and precise site locations, see Frest & Johannes (1995c, map D18)). The area has been affected by railroad usage and resort development. It is quite possible that a few additional sites exist on Shasta National Forest lands.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1992-1996, 1997.





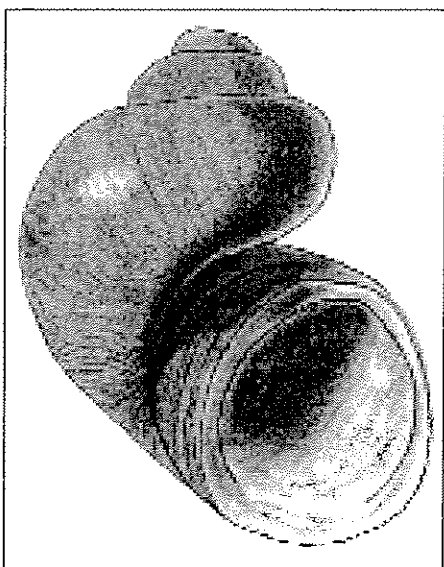
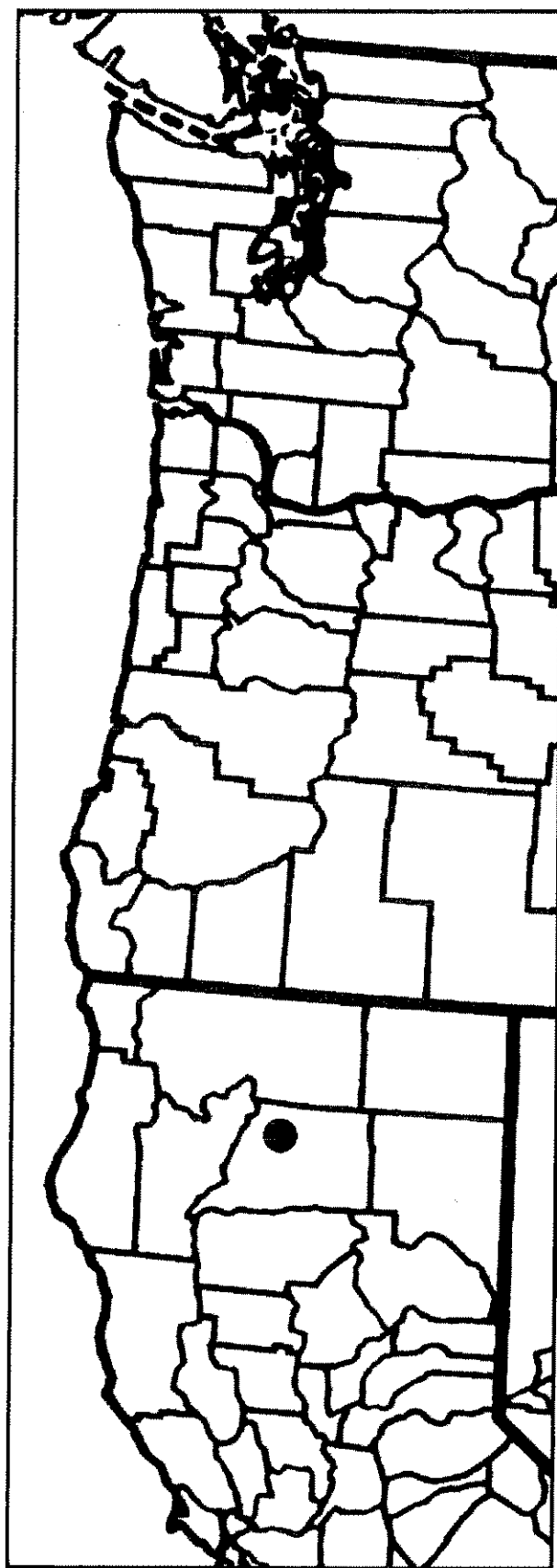


Figure 17. *Fluminicola* n. sp.  
17: actual height 3.7 mm.



Figure 18. *Fluminicola* n. sp.  
17: actual height 3.7 mm.



Map 8. Distribution of *Fluminicola* n.  
sp. 17.

*Fluminicola* n. sp. 18

[*Fluminicola* n. sp. 24 Frest & Johannes, in press]

globular pebblesnail

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## DESCRIPTION

*Fluminicola* n. sp. 24 is a small form, adult at 3.4-4.0 whorls. Height ranges from 2.2-3.0 mm in different populations; average 2.5-2.6; width subequal to height, range 2.2-2.7 mm, average 2.6; H/W ratio 0.98. Conch globular (**Figures 19 & 20**), often slightly wider than high; low, slanted protoconch (1.5 whorls; diameter 0.47 mm); teleoconch whorls very strongly convex, coiled evenly to nearly circular aperture; periphery well-rounded, with midpoint central on whorl; shell thin, almost clear, semi-translucent; periostracum yellow, clear; collabral growth lines almost completely obsolete. Aperture subcircular, with weakly and relatively evenly reinforced margin all around, but parietal callus is slightly thinner than columellar shelf; aperture complete across pariety. Columellar furrow distinct, very narrow, elongate, well excavated despite narrow width, with strong columellar ridge and several distinct, closely-spaced columellar grooves; complex originates at base of columella and quickly becomes subparallel to columellar shelf margin; continues past umbilicus barely onto parietal wall. Shell narrowly umbilicate; umbilicus wider than columellar furrow. Body lacks pigment or with only very scattered melanin granules; visceral coil also without obvious melanin or light gray, otherwise similar to that of *Fluminicola* n. sp. 15, except that eye spots in this taxon are much larger; penis seldom well-relaxed; narrow sickle-shape, pigmentless; operculum yellow.

## DISCUSSION

The relatively small size, thin, semi-transparent yellow shell, and low, globose conch are distinctive features for this drainage. There are similar rather low globose taxa in other drainages; but the comparative lack of dark body pigment is unusual for the genus. See **Key 3** for further comparisons. The first name applied to this taxon was *Fluminicola* n. sp. 18 (Frest & Johannes, 1993c, 1996a) and this is a Survey & Manage species under that name. In other works, this species was *Fluminicola* n. sp. 6 (Frest & Johannes, 1993d, 1994, 1995c, 1997) or *Fluminicola* n. sp. 24 (Frest & Johannes, in press): see Table 6 of Frest & Johannes (in press). Keep in mind that *Fluminicola* is a large and difficult genus (or soon will be), especially in drainages with numerous endemic taxa, as is the case here. We do not recommend identification of material from shells alone found in areas in which similar species are known or likely to occur.

## ECOLOGY

This crenocole species occurs in small springs and spring headwaters, and may be photophobic. It is found on the sides and underside of stones in shaded areas. Most sites have few to no macrophytes in those areas inhabited by this species, suggesting that the common hydrobiid lifestyle of perolithon grazer is that of this taxon also.

## ORIGINAL DISTRIBUTION

Portions of the upper Sacramento and Pit drainages in Shasta County, California.

## CURRENT DISTRIBUTION

Three sites in the upper Sacramento and Pit drainages (**Map 9**; for detailed map, see Frest & Johannes (1995c)); one site is in Shasta National Forest, on land included in DCA CD-82. It is likely that a few additional sites will be found in Shasta National Forest and on lands administered by Lassen National Forest.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1992-1996.



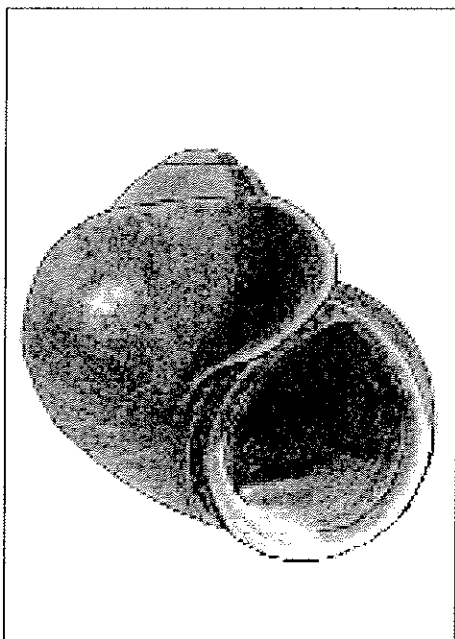
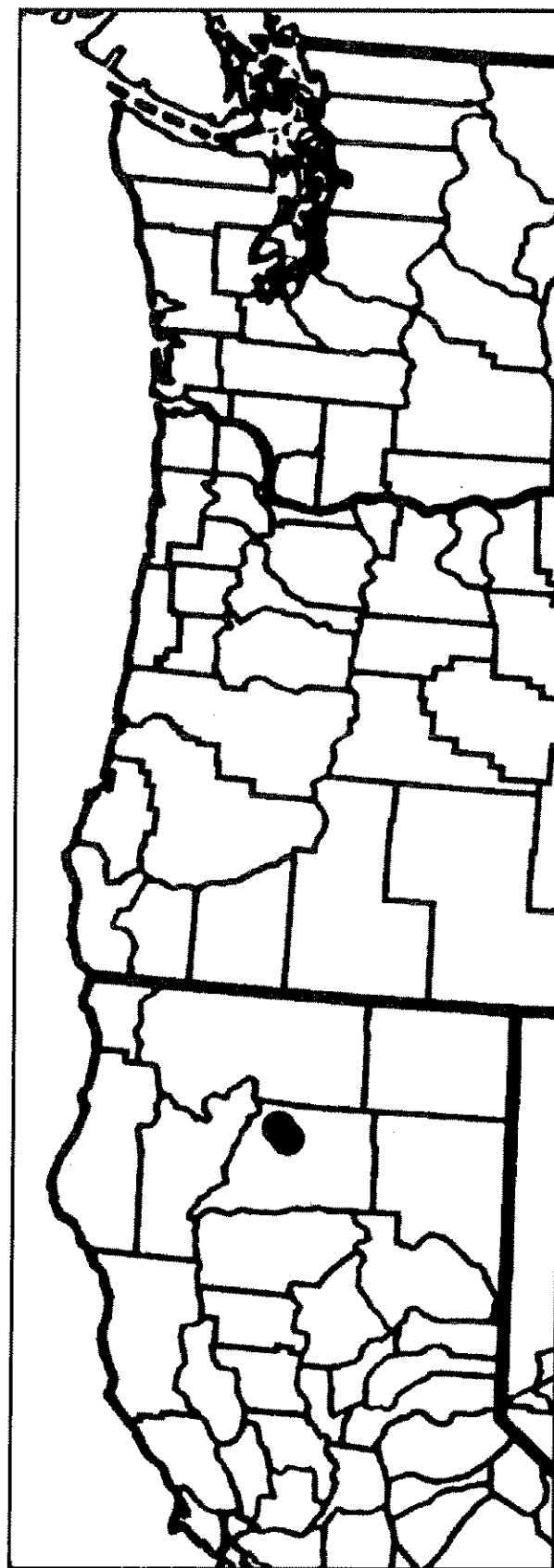


Figure 19. *Fluminicola* n. sp.  
18: actual height 2.6 mm.



Figure 20. *Fluminicola* n. sp.  
18: actual height 2.8 mm.



Map 9. Distribution of *Fluminicola* n.  
sp. 18.

*Fluminicola* n. sp. 19

[*Fluminicola* n. sp. 25 Frest & Johannes, in press]

umbilicate pebblesnail

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## DESCRIPTION

Conch moderate-sized for genus: 4.0-4.5 whorls at maturity; usually 4.4-4.7 mm in length (maximum observed 4.9 mm); width typically 3.9-4.1 mm; H/W ratio 1.14; spire low, globosely conic, with large flat protoconch (diameter 0.72 mm; 1.5 whorls) and very blunt apex (**Figures 21 & 22**). Lower (teleoconch) whorls strongly convex, very well rounded, with periphery widest at midpoint, although aperture slightly flattened basally; aperture shape subovate, very bluntly angled above, appears small (slightly narrow) in comparison to the preceding whorl; height 0.52 of full height. Last quarter whorl deflected slightly downward in mature individuals. Narrow columellar shelf and parietal callus, but basal and outer lip very thin. Umbilicus substantial, open; diameter about one-sixth to one-seventh full width; narrow columellar furrow, less wide than umbilicus but wider than columellar shelf; complete to base of columella; originates there, but oriented mostly subparallel to columella and disappears into umbilicus. Shell thin, opaque white; periostracum medium green, with occasional whitish radial streaks on early whorls; growth lines very indistinct. Body black, tentacles, snout, and neck completely so; rest of body slightly lighter; foot base medium gray; visceral coil is also very dark, brownish-black. Penis almost straight, rather stout blade with distinct terminal papilla; light gray epithelial pigment, with subepithelial darker bar centered on underside; operculum light orange-red.

## DISCUSSION

Possession of a definitely open umbilicus as an adult is unusual for *Fluminicola* generally; and there is only one other taxon in the Upper Sacramento drainage at all similar. This is the Lost Creek pebblesnail, ROD *Fluminicola* n. sp. 20 (*Fluminicola* n. sp. 26 in Frest & Johannes, in press). That taxon has a smaller umbilicus; taller spire; and more flattened whorls. See **Key 3** for comparisons with this and other Upper Sacramento-Pit drainage taxa. The Frest & Johannes (1993c, 1996a) and ROD (1994) name was *Fluminicola* n. sp. 19; in Frest & Johannes (1993d, 1994, 1995c, 1997) the appellation was *Fluminicola* n. sp. 7: see Table 6 of Frest & Johannes (in press) for the history of this taxon. This is a fairly distinctive species in terms of shell features, with only the Lost Creek pebblesnail at all similar locally (see next entry).

## ECOLOGY

Found among dense *Rorippa* and *Veronica* beds and on sandy-gravelly substrate in a large cold spring pool and adjacent spring runs; evidently a crenophile, periphyton and perolithon grazer.

## ORIGINAL DISTRIBUTION

Probably a very narrow endemic restricted to part of the Pit River drainage in Shasta County, California.

## CURRENT DISTRIBUTION

Limited thus far to a single spring complex in Lassen National Forest (**Map 10**; for smaller scale map, see Frest & Johannes (1995c, map D20)).

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1992.





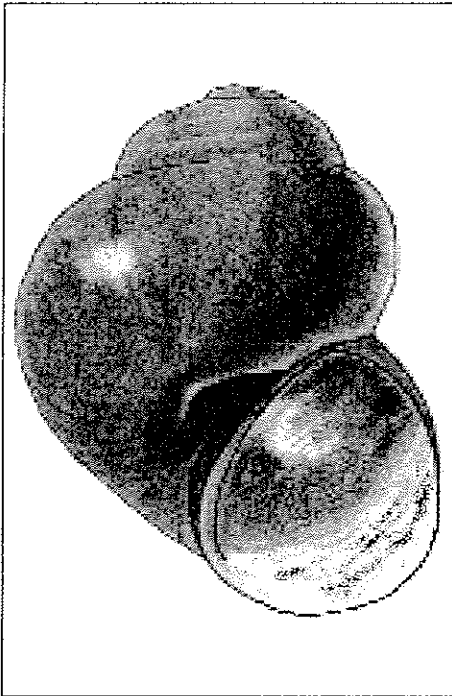
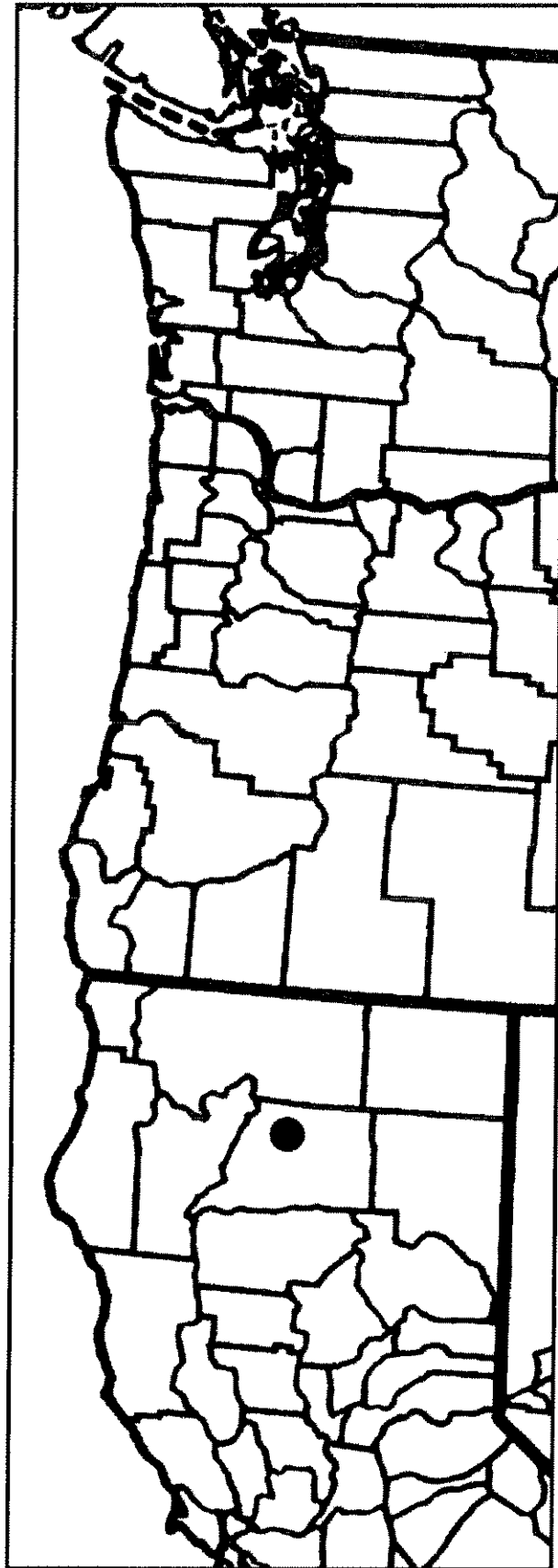


Figure 21. *Fluminicola* n. sp.  
19: actual height 4.6 mm.



Figure 22. *Fluminicola* n. sp.  
19: actual height 4.4 mm.



Map 10. Distribution of *Fluminicola* n.  
sp. 19.

*Fluminicola* n. sp. 20

[*Fluminicola* n. sp. 26 Frest & Johannes, in press]

## Lost Creek pebblesnail

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### DESCRIPTION

Conch with moderately tall conic spire (Figures 23 & 24), consisting of about 4.5 whorls at maturity (height ca. 2.5-3.0 mm, often ca. 2.7; width 2.0-2.1 mm; H/W ratio 1.34). Shell apex blunt (large, flat protoconch with 1.5 whorls, diameter 0.62 mm). Teleoconch whorls regularly coiled, slightly flattened sides but widest point at whorl midpoint; suture moderately impressed; shell thin, color opaque white; periostracum light green, often streaked heavily radially with white; ornament of very weak collabral growth lines only, most noticeable on last whorl. Aperture rounded, subcircular, with very blunt angle above; in contact with preceding whorl only along upper part of parietal wall; narrow columellar shelf and parietal callus, extending slightly onto outer lip; rest of outer and basal lip very thin and fragile. Umbilicus comparatively small, but large for genus, perhaps 0.50 mm in diameter; columellar furrow prominent, rather deeply excavated, filling most of umbilical opening, originating just above base of columella and extending into umbilicus, widening quickly until subparallel with columella; columellar ridge strong; columellar grooves numerous, distinct. Body medium gray on upper surface, base of foot lighter; tentacles, snout, and neck almost black; visceral coil medium gray; penis flattened stout blade with terminal papilla, no or very little epithelial pigment; subepithelial narrow central bar on underside; operculum light yellow.

### DISCUSSION

This species bears little resemblance to other Upper Sacramento-Pit taxa, with the exception of *Fluminicola* n. sp. 25 (Survey & Manage *Fluminicola* n. sp. 19): see Key 3 for comparisons. Note that the latter is quite a bit larger; has a shorter spire; has more rounded whorls; and the umbilicus is larger (wider). The ROD (1994) name, derived from Frest & Johannes (1993c, 1996a), was *Fluminicola* n. sp. 20; in Frest & Johannes (1993d, 1994, 1995c, 1997) it was *Fluminicola* n. sp. 8. Regionally, this taxon is quite distinctive in shell characters (as far as presently known), with the only other taxon having anywhere near as large an open umbilicus being the umbilicate pebblesnail (*q.v.*).

## ECOLOGY

Occurs in cold, swift-flowing water in a large spring-fed creek, generally near shore, both on sand-cobble substrate and on aquatic macrophytes and submerged portions of some emergents (*Rorippa*, *Cicuta*); periphyton and perolithon grazer; likely an omniphile.

## ORIGINAL DISTRIBUTION

Probably limited to small portions of the Pit drainage, Shasta County, California.

## CURRENT DISTRIBUTION

Known from a single creek in Lassen National Forest, Shasta County, California (**Map 11**; for detailed map, see Frest & Johannes (1995c, map D21)). This creek has been modified for small-scale hydropower development (PG & E); there are private inholdings on the drainage also.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1991-1992.



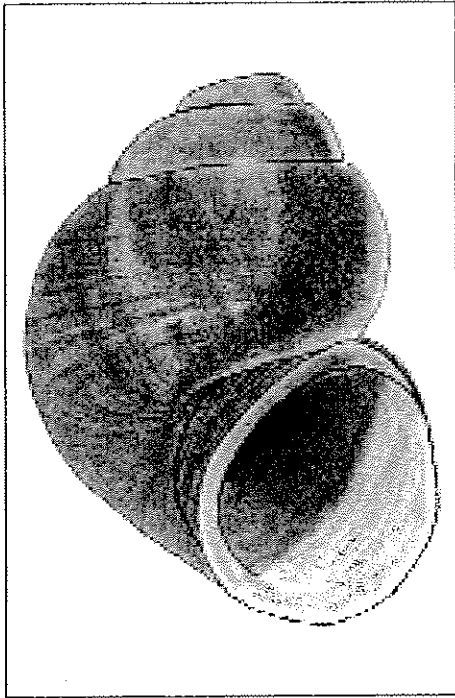
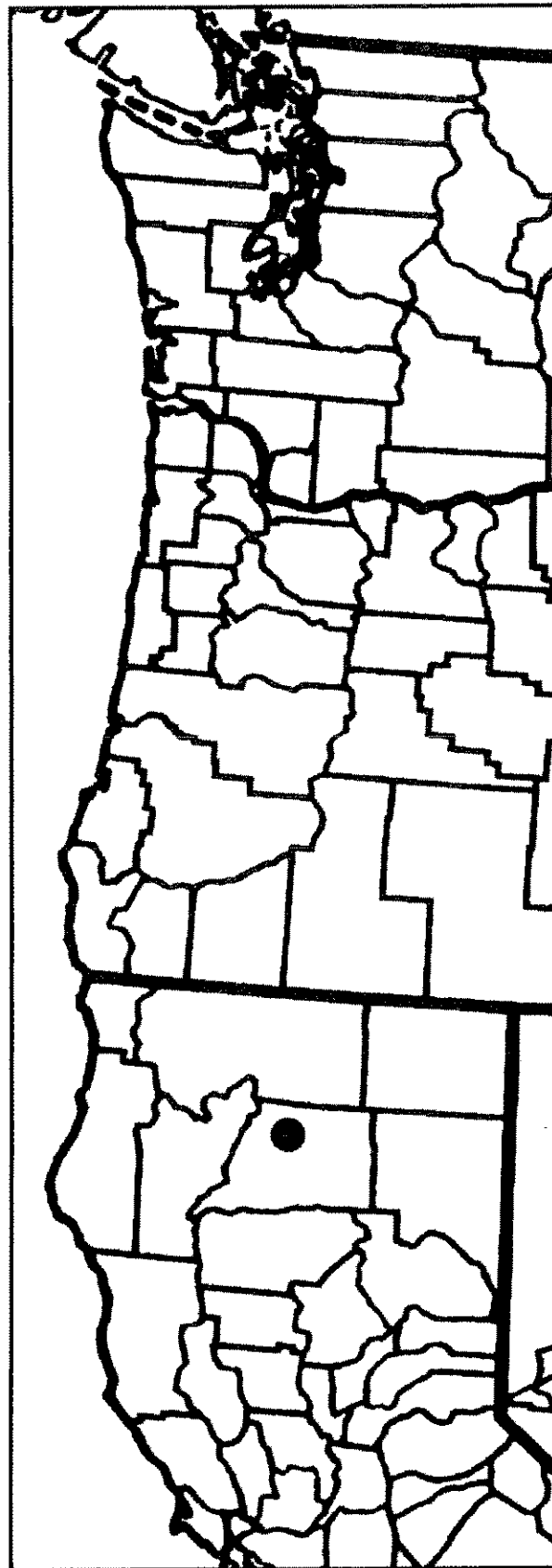


Figure 23. *Fluminicola* n. sp.  
20: actual height 2.7 mm.



Figure 24. *Fluminicola* n. sp.  
20: actual height 2.7 mm.



Map 11. Distribution of *Fluminicola* n.  
sp. 20.

*Fluminicola seminalis* (Hinds, 1842)  
[*Fluminicola seminalis* (Hinds, 1842) Frest &  
Johannes, in press]

nugget pebblesnail

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## DESCRIPTION

Conch globose or subglobose (**Figures 25 & 26**); large, 5.6-10.5 mm (most often ca. 8.3 mm height; width 4.7- 8.8 mm, often around 7.0 mm; adults with 4-4.5 whorls); spire short, H/W ratio 1.19; whorls convex, slightly shouldered above; protoconch small, rounded, 1.5 whorls, diameter ca. 0.62 mm. Umbilicus closed; aperture large, widely lunate, distinctly angled above, height 0.67 of shell height; small incomplete shallow lunate columellar furrow beginning at columellar midpoint and ending at columellar lip apex; columellar ridge not well developed; columellar grooves crowded, often indistinct; columellar shelf medium broad, well curved; slightly sinuous parietal wall merely glazed; outer and basal lips thin. Shell moderately thick, opaque white; periostracum opaque light green to yellowish green; ornament of very weak collabral growth lines and rare, very obscure spiral striae on some specimens. Snout and foot black; head medium grey to black; tentacles black except for eye spots; visceral coil also black. Penis large, curved sickle-shaped. Weak folds on proximal half; unpigmented except for dark epithelial pigment on proximal half and various amounts of distal subepithelial pigment.

This is a comparatively large taxon (reaching a maximum length of about 1 cm); the spire is depressed conic (almost globose) in shape; shell color is often green, and the shell is moderately thick. The body is dark gray or black except for the lower surface; the visceral coil is also dark gray or black. For complete description, see Hershler & Frest (1996); for regional comparisons, reference **Key 3**.

## DISCUSSION

Formerly sometimes incorrectly ascribed to other drainages, such as the Klamath: see discussion in Hershler & Frest (1996). This taxon seems characteristic of larger streams and large spring pools in the Sacramento system. Most if not all of the potamon populations appear to be extinct.

There is a substantial endemic *Fluminicola* species cluster in the Sacramento. However, few if any other Sacramento taxa reach this size (though smaller in large spring pools than in rivers); and the preferred swiftly flowing water (stream, especially) habitat is notable.

## ECOLOGY

“Large creeks and rivers” (Taylor, 1981, p. 153); prefers well-oxygenated streams and stable gravel-boulder substrates, regardless of stream size, in the cited range. Generally found at low elevations. Often associated with *Lanx patelloides* and with a high diversity of other mollusks. Also occurs commonly in large limnocyprids; populations in such habitats are often small-sized (5-7 mm height).

## ORIGINAL DISTRIBUTION

Sacramento River and Pit River, including a few large spring-fed tributaries in northern California (Shasta, Modoc, and Lassen counties). A related species is present in parts of the western Klamath drainage, California-Oregon (see entry for Crooked Creek pebblesnail (*Fluminicola* n. sp. 27: Frest & Johannes, in press) above).

## CURRENT DISTRIBUTION

Extinct over most of its former range in the Sacramento River, according to Taylor (1981) and personal observations. Appears to be extirpated in the upper Sacramento River (only 3 river miles unaffected after July, 1991 metam sodium spill into the river). Collected by us in the Pit River (California) system in Shasta County, California, including sites in the Shasta National Forest, and sites administered by Lassen National Forest (**Map 12**; for more detailed maps, see Frest & Johannes, 1995c, map D13, and Hershler & Frest, 1996). Known sites are in DCA OD-58; in DCA CD-82 and in or on the edge of DCA CD-81.

## REFERENCES

Taylor (1981); Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections 1991-1992, 1994-1996, 1997.



Key 4. Some Western US Species of Amnicolinae  
[Survey & Manage *Lyogyrus* n. sp. 1-3]

With the exception of "*Lyogyrus*" *greggi*, western US Amnicolinae (regarded as a separate family by Davis *et al.*, 1985; but see Ponder & Waren, 1988; Kabat & Hershler, 1993) were virtually unknown until the last seven years (see, e.g., Hershler & Thompson, 1988; Hershler & Holsinger, 1990; Frest & Johannes, 1998b). They are still typically rare and scattered, especially as compared to the nymphophylinid *Pyrgulopsis* and the characteristic western lithoglyphinids *Fluminicola* and *Pristinicola*. Most are as yet undescribed. Taxonomy of this subfamily is changing rapidly (see, e.g., Thompson & Hershler, 1991; Hershler, in press), so that the recent literature should be examined carefully and a specialist should be consulted before definite assignment of problematic Hydrobiidae possibly belonging to this group.

We do not recommend attempts to identify western "*Lyogyrus*" species from shells only, even when they are described species, if they come from a region like this, in which discovery of additional similar taxa is quite possible. Consultation with a specialist is *de rigueur* for this genus.

Hershler (in press) describes a new genus for "*L.*" *greggi* and "*Lyogyrus*" n. sp. 10, to which many of the western US species probably should be assigned. Both shell and anatomical features of this genus are distinctive. We use the name "*Lyogyrus*" until the new name is formally published. See also basic key and taxon entries in **SPECIES DISCUSSIONS** in Frest & Johannes (in press). All western forms so far examined differ from those of the eastern and central US in their paucispiral operculum, with subcentral, only slightly excentric nucleus; and in their penial arrangement (lobe originating near base, not about half way along filament, as in better-known eastern *Lyogyrus* and *Amnicola*: see Berry (1943); Thompson (1968, 1984); Hershler & Thompson, (1988); Thompson & Hershler (1991). Note that most Western *Lyogyrus*-like forms also have a flattened (near planar) protoconch, unlike most eastern forms (except *Lyogyrus* (*Spirogyrus*) *latus* and *Dasyscias franzi*: see Thompson & Hershler, 1991).

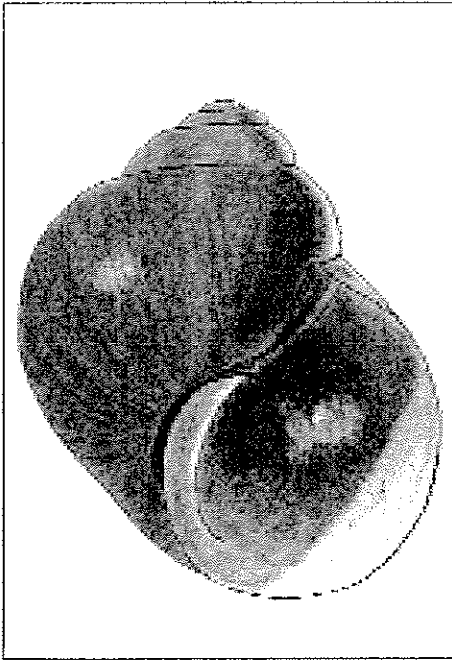
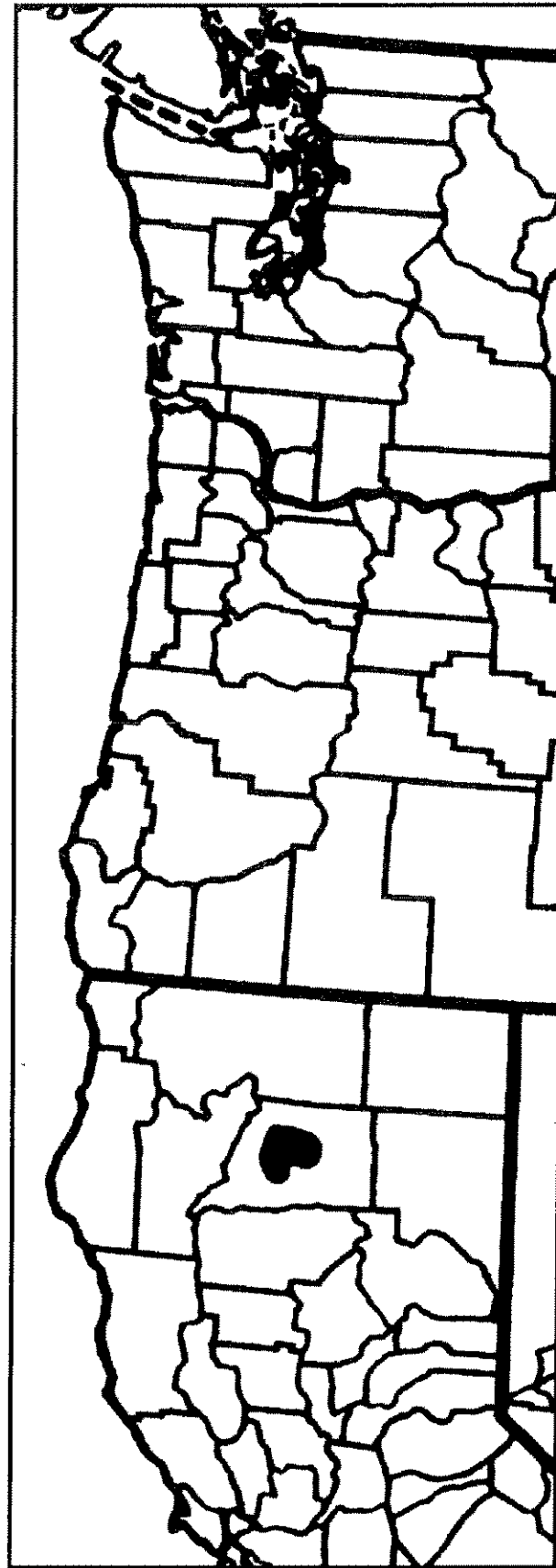


Figure 25. *Fluminicola seminalis* (Hinds, 1842): actual height 5.6 mm.



Figure 26. *Fluminicola seminalis* (Hinds, 1842): actual height 7.2 mm.



Map 12. Distribution of *Fluminicola seminalis* (Hinds, 1842)

(Key 4. continued)

- 1 Nuclear whorl of shell relatively large (0.38-0.48 mm in diameter); operculum weakly paucispiral, nucleus clearly excentric; penial lobe and filament relatively stout; lobe originates about halfway up filament ..... Genus *Amnicola* (no ROD species; only western species *Amnicola* n. sp. 1)  
Nuclear whorl of shell relatively small (0.29-0.36 mm in diameter); operculum paucispiral to nearly multispiral; nucleus subcentral; penial lobe and filament relatively slender; lobe originates near base of filament ..... Genus "*Lyogyrus*": 2
- 2 Shell very tall conic, 6-8 whorls; operculum almost multispiral ..... 3  
Shell depressed-moderately tall conic, 3-6 whorls; operculum definitely paucispiral ..... 4
- 3 Body light with mask of pigment around eyes, proximal end of snout, body sides; to 8 whorls, 4 mm height, unpigmented penial lobes ..... *Lyogyrus* n. sp. 2  
[ "*Lyogyrus*" n. sp. 2 Frest & Johannes, in press]  
Body light, no mask, to 6 whorls, 2.5 mm height, narrowly conic; penial filament pigmented ..... "*Lyogyrus*" n. sp. 6  
Frest & Johannes, in press
- 4 Shell off-white, light tan, or orange ..... 5  
Shell yellow ..... 10
- 5 Shell orange; to 1.5 mm height; 3 whorls, low-medium conic, black visceral coil, gray head, tentacles, and verge lobes ..... "*Lyogyrus*" n. sp. 7 Frest & Johannes, in press  
Shell off-white or light tan ..... 6
- 6 Spire strongly depressed to nearly flat; visceral coil black; head and tentacles light gray (a few melanin granules) verge lobes unpigmented; to 1.5 mm height; 3.5-4 whorls ..... "*Lyogyrus*" n. sp. 9 Frest & Johannes, in press  
Spire with taller spire; dome-shaped or low to medium conic ..... 7
- 7 Spire low conical, blunt top, ca. 1.5 mm height; 3 1/2 whorls; visceral coil black; light gray head and tentacles; unpigmented verge lobes ..... *Lyogyrus* n. sp. 1  
[ "*Lyogyrus*" n. sp. 1 Frest & Johannes, in press]  
Spire medium conical or dome-shaped; 1.5-2.5 mm height ..... 8

- 8 Spire with early whorls obviously dome-shaped; ca. 3.5 whorls;  
dark visceral coil and tentacles; body medium gray .....  
..... "*Lyogyrus*" n. sp. 10 Frest & Johannes, in press  
Spire medium or moderately tall conical ..... 9
- 9 Spire moderately tall conical, to 2.5 mm height, 4-5 whorls;  
black visceral coil; dark gray head, tentacles, and verge  
lobes ..... "*Lyogyrus*" *greggi* (Pilsbry, 1935)  
Spire medium conical, to 1.5 mm height, 4 whorls; black  
visceral coil; medium gray head and tentacles, verge lobes  
..... "*Lyogyrus*" n. sp. 5 Frest & Johannes, in press
- 10 Shell nodose, small (height 1.5 mm), medium conical, 3 whorls;  
transparent; body and visceral coil essentially pigmentless .....  
..... "*Lyogyrus*" n. sp. 4 Frest & Johannes, in press  
Shell almost smooth ..... 11
- 11 Shell about 1.5 - 2.0 mm in height, low conical, 3 whorls,  
transparent; light yellow; body and visceral coil almost  
pigmentless; verge lobes unpigmented .....  
..... "*Lyogyrus*" n. sp. 3 Frest & Johannes, in press  
Shell very small, about 1.5 - 1.9 mm height, depressed conical, 3  
whorls, transparent; canary yellow; body and visceral coil  
almost pigmentless; verge lobes unpigmented .....  
..... *Lyogyrus* n. sp. 3 [*"Lyogyrus"* n. sp. 8 Frest  
& Johannes, in press]

*Lyogyrus* n. sp. 1

[“*Lyogyrus*” n. sp. 1 Frest & Johannes, in press]

Columbia dusksnail

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## DESCRIPTION

Conch high conical except for blunt top (Figures 27 & 28), small (height ranges from 1.4-2.3 mm; average close to 1.7 mm; width usually 1.4 mm; H/W ratio 1.29); small, flat protoconch of 1.3 whorls, diameter ca. 0.40 mm.; upper whorls broadly domed, last 1.5-2.0 whorls more normally coiled; whorls 3.5-4.0. Final whorls strongly rounded, with periphery even, midpoint at whorl center; suture deeply impressed. Shell off-white, light gray, or light tan and translucent, thin; periostracum clear or slightly yellowish; part or all of shell commonly with rust to black coating. Aperture oval, prominent (height 0.52 of shell height), broadly angled above, barely in contact on upper left side with preceding whorl (adnate); aperture barely reinforced along columellar and parietal walls; outer lip very thin, fragile. Umbilicus moderate-sized, open; diameter about one-fifth to one-sixth full width. No columellar complex present. Body and tentacles evenly light grey; visceral coil black; both penial lobes unpigmented, penial filament, long, thin, circular in cross section, tip tapered, bluntly pointed; accessory lobe arises from base of penial filament. Operculum near circular, colorless peripherally, darker (orange) at subcentral nucleus; paucispiral.

## DISCUSSION

The species somewhat resembles taxa from the Blue Mountains (Oregon) and from southeastern Idaho and adjacent parts of southwestern Montana and western Wyoming; but the Blue Mountains “*Lyogyrus*” has a larger, more evenly conical orange shell; different body pigment pattern; and slightly different male genital anatomy. *Lyogyrus greggi* has a much larger, more attenuate spire; darkly pigmented body; and pigmented penis. “*Lyogyrus*” n. sp. 10 has an even more dome-shaped spire, with the spire height and width nearly equal. Consultation with Key 4 may be helpful. This taxon was cited as “*Lyogyrus*” n. sp. 1 in Frest & Johannes (1993c, 1995a, 1996a, in press): see Table 6 of Frest & Johannes (in press).

The genus *Lyogyrus* has recently been split into subgenera (Thompson & Hershler, 1991; see also Hershler & Thompson, 1988). However, the detailed anatomy of all of the western and some of the eastern US species remains to be elucidated. It is clear that most of the western species do not belong to any described subgenus. Note that, until

recently, "*Lyogyrus*" *greggi* and *Amnicola limosa* (s.l.) were the only known western US taxa and most of the West was thought to lack amnicolinids (Hershler & Holsinger, 1990, fig. 5). Additional taxa are quite possible. Hershler (in press) erects a new genus for "*Lyogyrus*" *greggi* and another new taxon; it is likely that this species belongs to the same genus.

## ECOLOGY

Springs and spring outflows, from low to high elevations, in cold, pure, well-oxygenated water. Often in very small springs; most common on soft substrates, in shallow, rather slow flows. Prefers oligotrophic very cold pristine flowages with no macrophytes, but can be found in larger springs with *Rorippa* and *Cicuta*. Sometimes found with other Sensitive species, such as *Juga* (*Oreobasis*) spp., especially in the Columbia Gorge. An especially common associate is *Pristinicola hemphilli* (q.v.). This crenocole taxon has been noted on both mud and coarse substrate; it appears to feed mostly as a perolithon and periphyton grazer, even in muddy areas.

## ORIGINAL DISTRIBUTION

This species is a Columbia Gorge endemic, found on both sides from east and south of Portland to Hood River, Oregon. Most sites are in Gorge tributaries; a few other sites occur in drainages originating from near Mount Hood, Oregon, to Mount St. Helens, Washington. We have not found this form on the west side of the Cascades in Washington, nor on the west side of the Willamette Valley in Oregon except in the immediate Portland area. Similarly, it seems to be absent from the Deschutes River and its major tributaries in Oregon and from the central and southern Willamette Valley, Oregon.

## CURRENT DISTRIBUTION

Very sporadic in the central and eastern Columbia Gorge, Washington and Oregon (**Map 13**). About a dozen sites are known from private lands and from the Columbia Gorge National Scenic Area, Gifford Pinchot National Forest, and Mount Hood National Forest, Klickitat and Skamania counties, Washington, and Multnomah, Clackamas, and Hood River counties, Oregon. Some sites are in Washington or Oregon state parks (Beacon Rock, Benson, Wahkeena Falls). Recently (1998) extended to the Cowlitz/Clark/Skamania County border. This species is associated with federal listing candidate arthropods at some localities.

## REFERENCES

Frest & Johannes (1993c; 1995a; 1996a; in press); ROD (1994); Deixis collections, 1988-1991, 1994, 1996-1999.

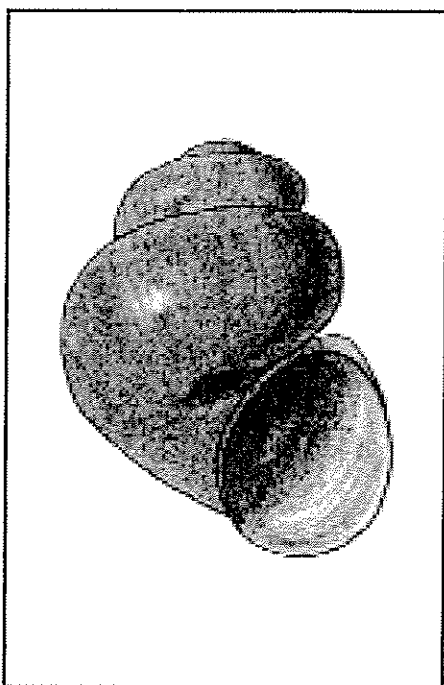
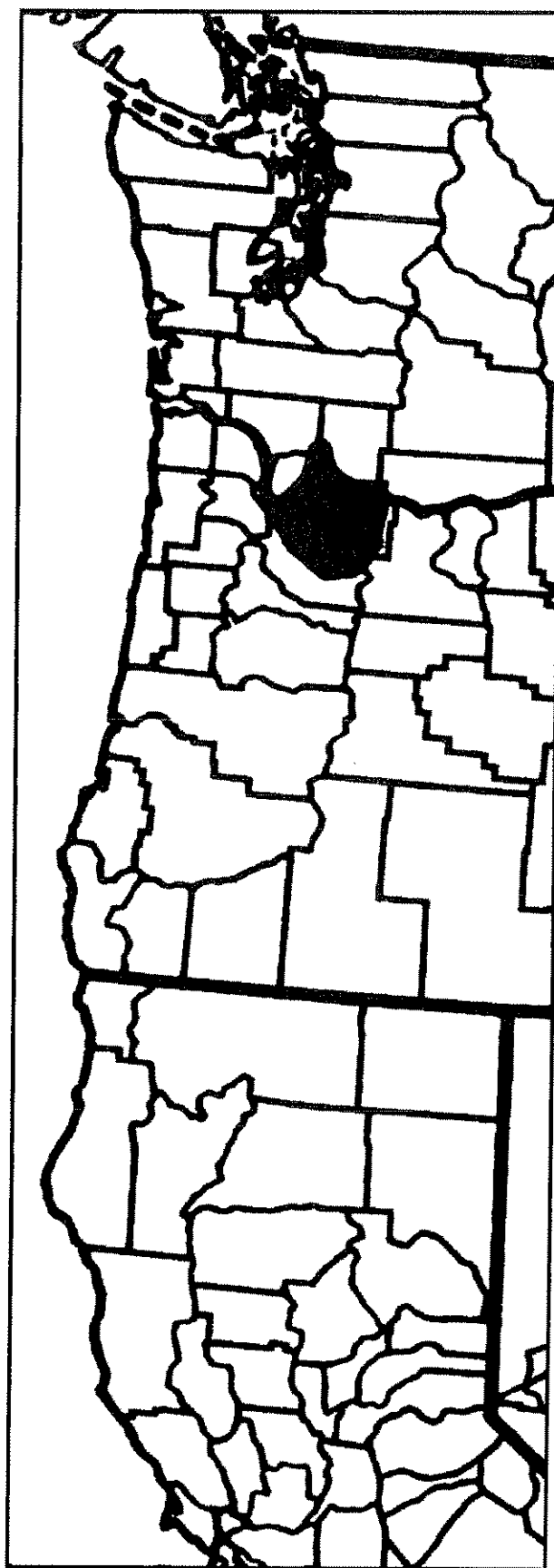


Figure 27. *Lyogyrus* n. sp. 1:  
actual height 2.2 mm.



Figure 28. *Lyogyrus* n. sp. 1:  
actual height 2.0 mm.



Map 13. Distribution of *Lyogyrus* n.  
sp. 1.



*Lyogyrus* n. sp. 2

[“*Lyogyrus*” n. sp. 2 Frest & Johannes, in press]

## Washington duskysnail

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### DESCRIPTION

Conch large for genus (Figures 29 & 30: height 3.0-5.2 mm, width 2.1-3.0 mm at 5-8 whorls (adults)), H/W ratio 1.43-1.8; very high-spired, tall, with very evenly convex whorls after initial whorls, periphery well-rounded, with outermost point at whorl edge center, suture very deep; flat protoconch of 1.3 whorls, diameter 0.4 mm. Last 0.25 whorl slightly descending, aperture almost circular, barely compressed laterally, barely detached; unreinforced, very thin margin all around, height makes up 0.37-0.20 total height, lip even. Shell clear to partly translucent, very thin; periostracum clear, color ranges from clear to tinged with yellow or tan; ornament of collabral growth lines only, often very faint; many specimens with partial coating of dark brown-black matter. Umbilicus open, moderate in size, contained in full width ca. 4.5 times. Mantle light in color; cephalic tentacles light, with single distinct narrow central yellow bands on upper surfaces when live; “mask” of black pigment on neck and around and between eyes (see cover illustration and Figure 2). Operculum near circular, colorless peripherally, darker (orange) at subcentral nucleus; paucispiral.

### DISCUSSION

The shell shape and pigment pattern are distinctive as compared to previously described forms. This species more closely resembles eastern US species than do most of the recently discovered western novelties. This taxon was cited as *Lyogyrus* n. sp. 2 in Frest & Johannes (1993c; 1995a; 1996a; in press); see Table 6 of Frest & Johannes (in press); the common name in the latter is masked duskysnail. For comparisons with other amnicolinid taxa, see Key 4. Note that Hershler (in press) erects another genus for “*Lyogyrus*” *greggi*; of all the western forms known to date, this one is most variant and most closely resembles eastern forms, even though it, too, has a paucispiral operculum and the penial lobe originates near the base of the penial filament.

## ECOLOGY

Kettle lakes on the periphery of the Columbia drainage in northern and central Washington, in areas heavily affected by Late Pleistocene glaciation. This limnophile species occurs on oxygenated mud substrates in areas with some aquatic macrophytes (*Potamogeton crispus*, *Elodea*, *Myriophyllum spicatum*, *Ceratophyllum densum*, *Chara*). Sizable numbers of waterlogged deciduous leaves (*Alnus*, *Populus*) are always present. Occurs with another rare endemic (partly outside the range of the Northern Spotted Owl), *Amnicola* n. sp. 1 at one site. This pelophile species appears to graze periphyton from leaf and other plant fragment surfaces and from other hard objects; but may be a detritivore as well.

## ORIGINAL DISTRIBUTION

Probably quite common at one point in northern and central Washington on the east side of the Cascades east to the Rocky Mountains, in heavily glaciated valleys, in Pend d'Oreille, Stevens, Ferry, Okanogan, and Chelan counties, Washington. This taxon could also be found in adjacent parts of the Idaho Panhandle and northwestern Montana with similar geologic history.

## CURRENT DISTRIBUTION

Known from two large kettle lakes, one in Ferry County and the other in Wenatchee National Forest, Chelan County, Washington (**Map 14**).

## REFERENCES

Clarke (1976b); Frest & Johannes (1993c, 1995a, 1996a, in press); ROD (1994); Deixis collections, 1988-1993, 1996.



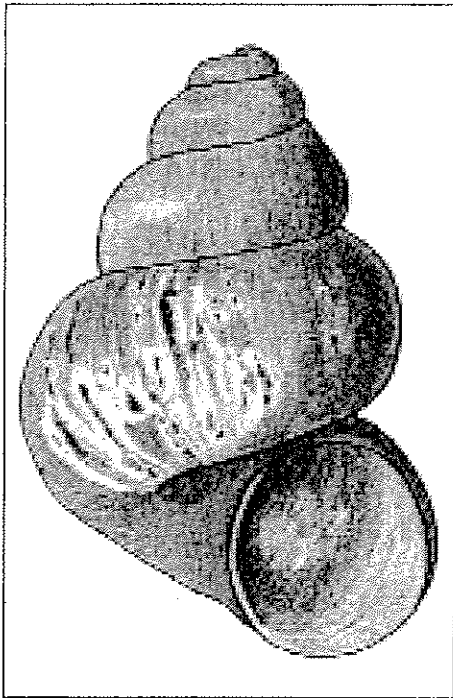
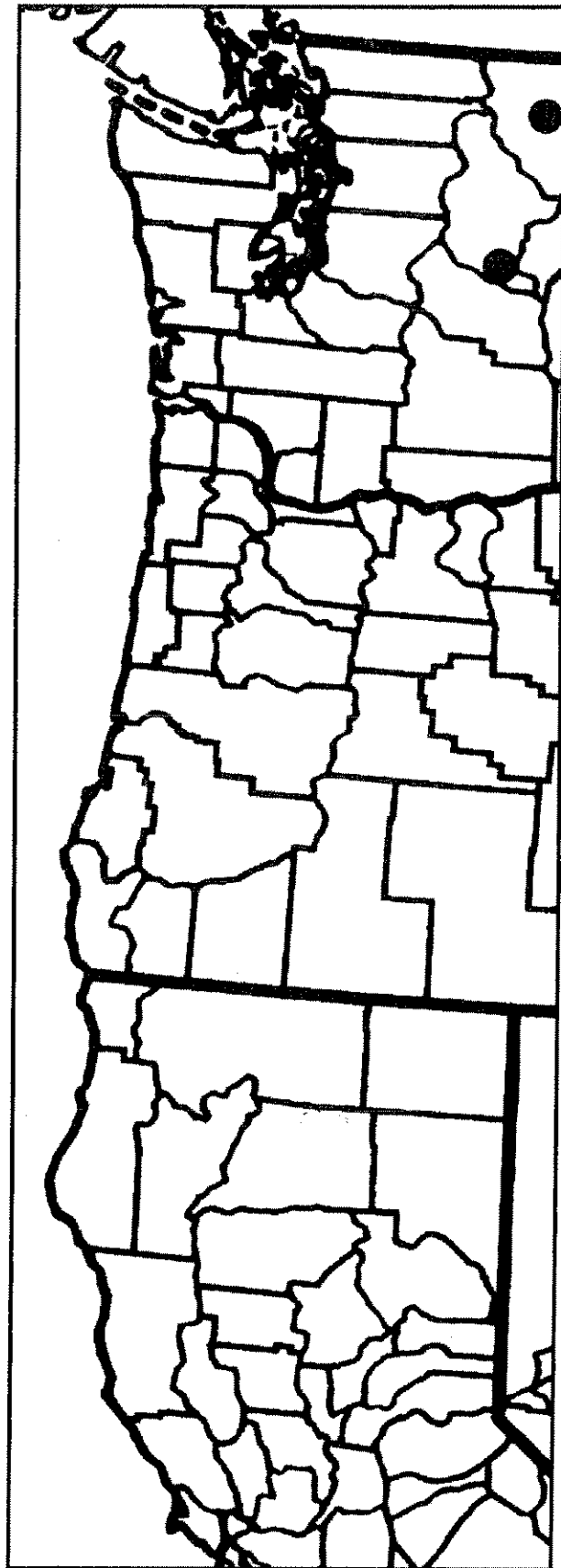


Figure 29. *Lyogyrus* n. sp. 2:  
actual height 3.3 mm.



Figure 30. *Lyogyrus* n. sp. 2:  
actual height 3.3 mm.



Map 14. Distribution of *Lyogyrus* n.  
sp. 2.

*Lyogyrus* n. sp. 3

[ "*Lyogyrus*" n. sp. 8 Frest & Johannes, in press]

canary duskysnail

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## DESCRIPTION

Conch subturberate to low conical; very small taxon (height 1.5-1.9 mm when adult; width 1.4-1.8 mm; H/W ratio 1.10: adult with 3.0-3.25 whorls: **Figures 31 & 32**); protoconch with 1.2 whorls, flattened, diameter ca. 0.33 mm; teleoconch whorls evenly rounded, very convex, loosely attached, nearly circular; suture deeply impressed; periphery outermost point at whorl midpoint; aperture nearly circular, height 0.58 full shell height, very bluntly angled above, adnate, in contact with last whorl only along narrow portion of parietal wall; reinforced only along columellar wall (very narrow columellar shelf); parietal, outer and basal lips very thin, fragile. Umbilicus moderate-sized, open; diameter approximately one-seventh full shell diameter; aperture slightly inclined forward (prosocline), sinuous, with small lappet on upper portion of outer edge, about one-third of outer lip length, extending only slightly forward. Columellar furrow present; small, lunate, very narrow, situated high on columellar edge and extending barely onto parietal wall and not into umbilicus; columellar ridge not prominent; columellar grooves numerous, not easily distinguishable; columellar furrow only shallowly excavated, width about equal to columellar shelf. Shell yellow, transparent, thin; periostracum clear to slightly yellowish or brownish, very thin; growth lines very faint, crowded, usually not easily visible; shell sometimes with dark brown to black coating, seldom over whole shell. Body essentially pigmentless except for eyes, sometimes with very rare scattered melanin granules; male genitalia generally pigmentless, with very long, thin, slowly tapering, distally pointed penis; penis often longer than shell, sometimes loosely spirally coiled (as preserved); accessory lobe originating at penis base, long, thin, but seldom more than two-thirds length of penial filament, not coiled.

## DISCUSSION

This taxon is compared to others in the western US in **Key 4**. The only two other western US species closely similar are from the Upper Klamath Lake drainage. The nodose duskysnail, "*Lyogyrus*" n. sp. 4, has prominent nodes on the mature whorls. "*Lyogyrus*" n. sp. 3 is slightly larger and has a less depressed spire. Note that Hershler (in press) erects another genus for *Lyogyrus greggi* and a new taxon. This form may also belong to the same genus. Recorded under the name

*Lyogyrus* n. sp. in Frest & Johannes (1993d, 1994); as *Lyogyrus* n. sp. 3 in Frest & Johannes (1993c, 1995c, 1996a, 1997); and as "*Lyogyrus*" n. sp. 8 in Frest & Johannes (in press).

## ECOLOGY

Occurs on underside of loose but stable cobbles and boulders in very large spring; many rocks with abundant encrusting red algae; most common in water less than 4' deep. Appears to be photophobic. Typically found with other Species of Special Concern, e.g., *Vorticifex* n. sp. 1 and *Juga* (*Calibasis*) *acutifilosa*.

## ORIGINAL DISTRIBUTION

Uncertain; likely confined to major spring complexes in the Pit drainage; a sister species occurs in slightly different habitat in the Klamath drainage, Oregon. Probably confined to parts of Shasta, Lassen, and Modoc counties, California.

## CURRENT DISTRIBUTION

Known definitely from a single site in Shasta County, near the present boundary of Shasta National Forest (**Map 15**; for detailed map, see Frest & Johannes (1995c)). Other sites are possible in limited areas on BLM lands and in Lassen and Shasta National Forests in the vicinity of Fall River Mills and Hat Creek.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1990-1992, 1997.

## FAMILY PLEUROCERIDAE

### Key 5. Some ROD *Juga* Species and Related Taxa [Survey & Manage: *Juga (Oreobasis)* n. sp. 2 & 3]

For proper determination of western pleurocerids it is necessary to have representation of nearly the full ontogeny. Subgenera as defined by Taylor (1966) are distinguished by the morphology of the earliest 3-4 whorls, often lost on older specimens. A number of new taxa have been noted over the past seven years; and it is likely that others remain. Ambiguous lots should be determined by a specialist. This key does not include all presently known taxa, but should be useful for distinguishing most Sensitive taxa from the common described forms in the range of the Northern Spotted Owl. Note that there are many more undescribed than described taxa; and that others undoubtedly remain to be found. Consultation with a specialist may be helpful here.

A number of features other than those of the juvenile may prove useful. For example, while all western pleurocerids observed so far have similar egg mass morphology (large, stringy, elongate masses with numerous unordered eggs, *contra* Branson (1977)), color varies between taxa from white to yellow, brown, and blue. Body color, pigmentation pattern, and sole color differ significantly as well, as do many anatomical features. Terminology of these taxa has evolved through our various reports; see Frest & Johannes (in press, Table 6) for summary.

- 1 First few whorls smooth or with a few scattered vertical plicae ..... subgenus *Oreobasis*: 2  
First few whorls with numerous regular horizontal plicae or lirae ..... 10
- 2 Whorls well-rounded (strongly convex) ..... 3  
Whorls slightly flattened to flattened ..... 4
- 3 Whorls strongly convex; large, short spire with prominent black and yellow bands ..... *Juga (Oreobasis) bulbosa* (Gould, 1847)  
Whorls moderately convex; medium-sized, more attenuate spire; bands amber and reddish black .....  
*Juga (Oreobasis)* n. sp. 4 Frest & Johannes, in press
- 4 Nacre completely purple ..... 5  
Nacre generally white ..... 6

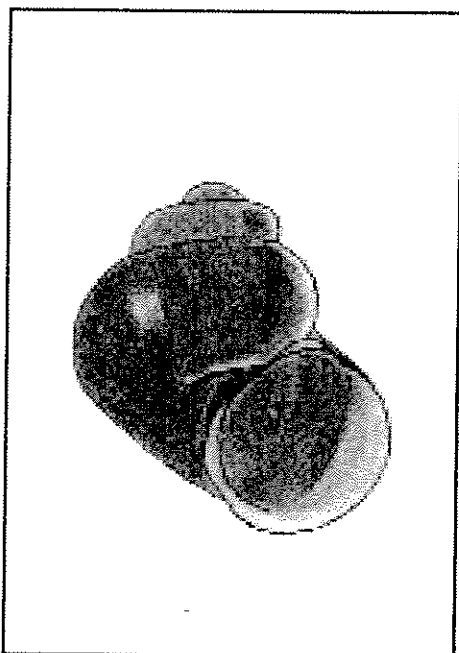
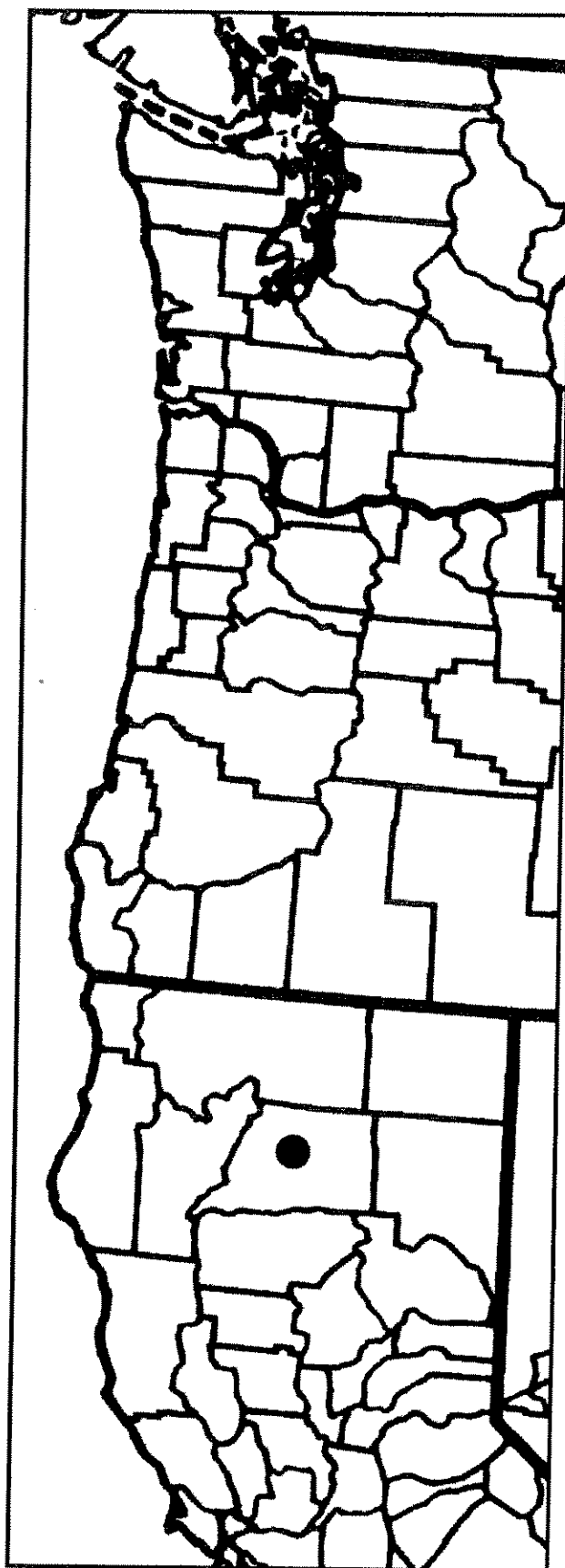


Figure 31. *Lyogyrus* n. sp. 3:  
actual height 1.8 mm.



Figure 32. *Lyogyrus* n. sp. 3:  
actual height 1.6 mm.



Map 15. Distribution of *Lyogyrus* n.  
sp. 3.



- 5 Whorls nearly flat; suture not prominent; periostracum evenly  
deep brown ..... *Juga* (O.) n. sp. 3 Frest & Johannes, in press  
Whorls flattened; suture deep, channeled; periostracum even  
deep cinnamon red except for narrow yellow band at suture  
(not always present) ..... *Juga* (*Oreobasis*) n. sp.  
3 [*Juga* (*Oreobasis*) n. sp. 6 Frest & Johannes, in press]
- 6 Teleoconch large, bandless, slightly yellowish dark green .....  
..... *Juga* (*Oreobasis*) n. sp. 5 Frest & Johannes, in press  
Teleoconch banded ..... 7
- 7 Single, near central reddish band; whorls slightly convex,  
greenish yellow; nacre white ..... *Juga* (*Oreobasis*)  
n. sp. 1 Frest & Johannes, in press  
Multiple bands ..... 8
- 8 Bands multiple, several colors, distinct; whorls nearly flat;  
conch relatively low ..... *Juga* (*Oreobasis*) n. sp. 2  
[*Juga* (*Oreobasis*) n. sp. 2 Frest & Johannes, in press]  
Bands multiple, weak; whorls slightly convex ..... 9
- 9 Teleoconch small (< 15 mm); medium brown, with weak darker  
peripheral band; nacre off-white .....  
..... *Juga* (*Oreobasis*) *chacei* (Henderson, 1935)  
Teleoconch large (to 25 mm); upper whorl dark reddish-brown,  
with two faint yellowish bands; lower whorl horn-colored, with  
dark reddish basal band; columella purple; nacre otherwise  
white ..... *Juga* (*Oreobasis*) *orickensis* (Henderson, 1935)
- 10 Early whorls with one to several strong lirae only .....  
..... subgenus *Calibasis*: 11  
Early whorls with numerous, closely-spaced vertical plications  
..... subgenus *Juga*: 12
- 11 Conch tall, attenuate, reddish-brown, whorls slightly flattened,  
with lirae variably developed on adult .....  
..... *Juga* (*Calibasis*) *acutifilosa* (Stearns, 1890)  
Conch shorter, yellow-green, whorls moderately convex, with  
strongly developed, numerous adult lirae .....  
..... *Juga* (*Calibasis*) *occata* (Hinds, 1844)
- 12 Plications generally continue to last whorl ..... 13  
Plications confined to upper half of conch ..... 14

- 13 Whorls generally moderately convex; lirae moderately strong; color greenish-yellow; nacre white; plications coarse .....  
..... *Juga (Juga) plicifera plicifera* Lea, 1838  
Whorls relatively flat; plications relatively fine; a few weak lirae; color medium brown; sometimes with single reddish -brown central band ..... *Juga (Juga) hemphilli* n. subsp. 1 Frest & Johannes, in press
- 14 Whorls more or less convex ..... 15  
Whorls more or less flattened ..... 18
- 15 Plications reaching about half or less down teleoconch; color uniform ..... 16  
Plications reaching half or less down teleoconch; banded ..... 17
- 16 Color uniform yellow-green; lirae numerous, moderate in strength; conch moderately tall .....  
..... *Juga (Juga) hemphilli dallesensis* (Henderson, 1935)  
Color uniform brown; lirae weak; moderately impressed suture; conch moderately tall; nacre white; usually not decollate .....  
..... *Juga (Juga)* n. sp. 3 Frest & Johannes, in press
- 17 Color dark yellow with two reddish, narrow bands; lirae moderate in number and strength; conch tall, narrow; nacre white; plicae usually extend about half way down spire .....  
..... *Juga (Juga) silicula silicula* (Gould, 1847)  
Color light yellow with two reddish bands, the lower wide; lirae numerous, weak; conch tall, narrow; whorls less convex than above; plicae usually confined to upper quarter of teleoconch .....  
..... *Juga (Juga) silicula shastaensis* (Lea, 1856)
- 18 Color more or less uniform ..... 19  
Bands distinct ..... 20
- 19 Spire with nearly flat sides except for moderately impressed sutures; medium brown, with weak subperipheral band; nacre white; not usually decollate; plications strong, to about 1/3 way down teleoconch; a few weak lirae .....  
..... *Juga (Juga) hemphilli hemphilli* (Henderson, 1935)  
Spire taller, with flattened whorls; suture not strongly impressed; dark brown, unbanded; nacre brownish; no lirae; commonly decollate, with plicae lost .....  
..... *Juga (Juga)* n. sp. 1 Frest & Johannes, in press

- 20 With two narrow bands ..... 21  
 Three-5 red-brown bands; yellow background; weak plications;  
 short spire; white nacre .....  
 ..... *Juga (Juga)* n. sp. 2 Frest & Johannes, in press
- 21 Medium yellow with two narrow brown bands; scattered nearly  
 obsolete lirae; large; light purple nacre .....  
 ..... *Juga (Juga) hemphilli maupinensis* (Henderson, 1935)  
 Dark yellow-brown with two medium-width, dark brown bands;  
 nacre white .....  
 ..... *Juga (Juga) hemphilli* n. subsp. 2 Frest & Johannes, in press



*Juga (Oreobasis)* n. sp. 2

[*Juga (Oreobasis)* n. sp. 2 Frest & Johannes, in press]

basalt juga

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## DESCRIPTION

Conch moderate-sized (**Figures 33 & 34**: typical individual with eroded apex: height 22.1 mm; width 9.5 mm; H/W ratio 2.33), moderately high-spired *Juga* with barely convex whorls and comparatively shallowly suture; outermost whorl point just below whorl midpoint on teleoconch whorls. Nacre white to semitransparent; shell thick, with periostracal groundcolor yellowish; bands 3 to numerous, generally with three yellow and several brown, pink, white, or tan; or some combination of these; tan bands often three: one wide, near whorl midpoint; one narrow, subperipheral center; one narrow, suraperipheral center; white band often just below suture; initial teleoconch whorls often dark bluish purple or bluish black; periostracum ornamented with collabral, very weak growth lines; very rare and obsolete striae, if any. Spire not often with organic/mineral coating; periostracum shiny. Initial whorls (protoconch) smooth; very high spired and very convex, 1 mineral deep reddish-brown. Eroded adults typically retain 5.5-6.5 whorls. Aperture typical for *Juga*, rounded lunate, height 0.38 eroded adult spire total height; fairly angled adapically; outer lip thin; but shell thickened slightly internal to peristome; tan periostracal bands visible within; peristome thickened slightly to form very narrow columellar shelf (shelf nacre white); shelf curved; outer edge of basal lip slightly reflected; parietal lip merely a clear glaze; anomphalous.

## DISCUSSION

This species may look much like *Juga (Juga)* n. sp. 1 [three-band juga] if the initial whorls are absent; but that species generally has a much more consistent dark brown and yellow banding pattern, and generally retains enough of the early whorls that the plications, though weak, are easily visible. The basalt juga also has a somewhat more stout spire. This species was previously cited as *Juga (Oreobasis)* n. sp. 2 by Frest & Johannes (1993c, 1995a, 1996a, in press): see Table 6 of Frest & Johannes (in press) for complete name history. For additional comparisons with related taxa, see Key 5.

## ECOLOGY

A crenophile, restricted to springs in small drainages tributary to the Columbia River in the Columbia Gorge, at low elevations. Prefers gravel substrate and requires unpolluted water; mostly in very small and shallow but permanent, undisturbed springs. These commonly have abundant *Rorippa* and local *Mimulus*; immediately surrounding vegetation may include *Urtica*, *Rubrus*, and *Cornus stolonifera*. The surrounding terrestrial plant community is predominantly sage scrub if intact; pastured areas commonly have blackberry thickets. This species is often the dominant mollusk at a site: the most common freshwater mollusk associate is *Pisidium insigne*. Occasionally, this species occurs with *Juga* (*Juga*) n. sp. 1 [three-band juga, q.v.] or with *Pristinicola hemphilli*. The same spring and associated talus may have such land snail species as *Vespericola depressus*, *Monadenia fidelis minor*, or *Oreohelix variabilis*. Generally a perolithon feeder and lithophile.

## ORIGINAL DISTRIBUTION

Uncertain; recently discovered taxon. Probably central and eastern Columbia Gorge only.

## CURRENT DISTRIBUTION

Sporadic in springs in the central and eastern portions of the Columbia Gorge, Oregon side only: Hood River and Wasco counties, Oregon, including sites in Mount Hood National Forest and sites in Columbia Gorge National Scenic Area (**Map 16**). We have surveyed much of the Columbia Gorge in some detail; it is very unlikely that further work will greatly enlarge the geographic distribution or add substantially to the number of known sites.

## REFERENCES

Frest & Johannes (1993c; 1995a; 1996a; in press); ROD (1994); Deixis collections, 1988-1993. One very old museum lot in NMNH may be this species.



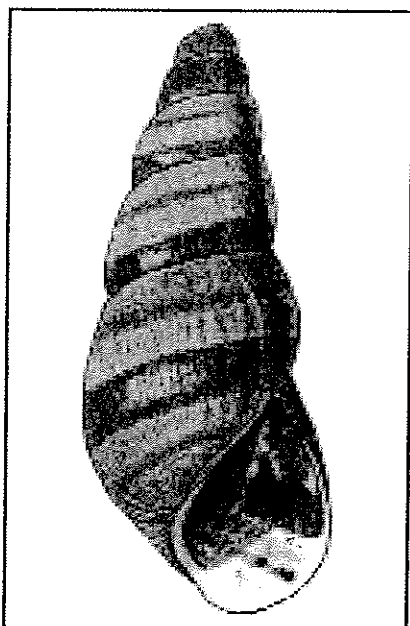
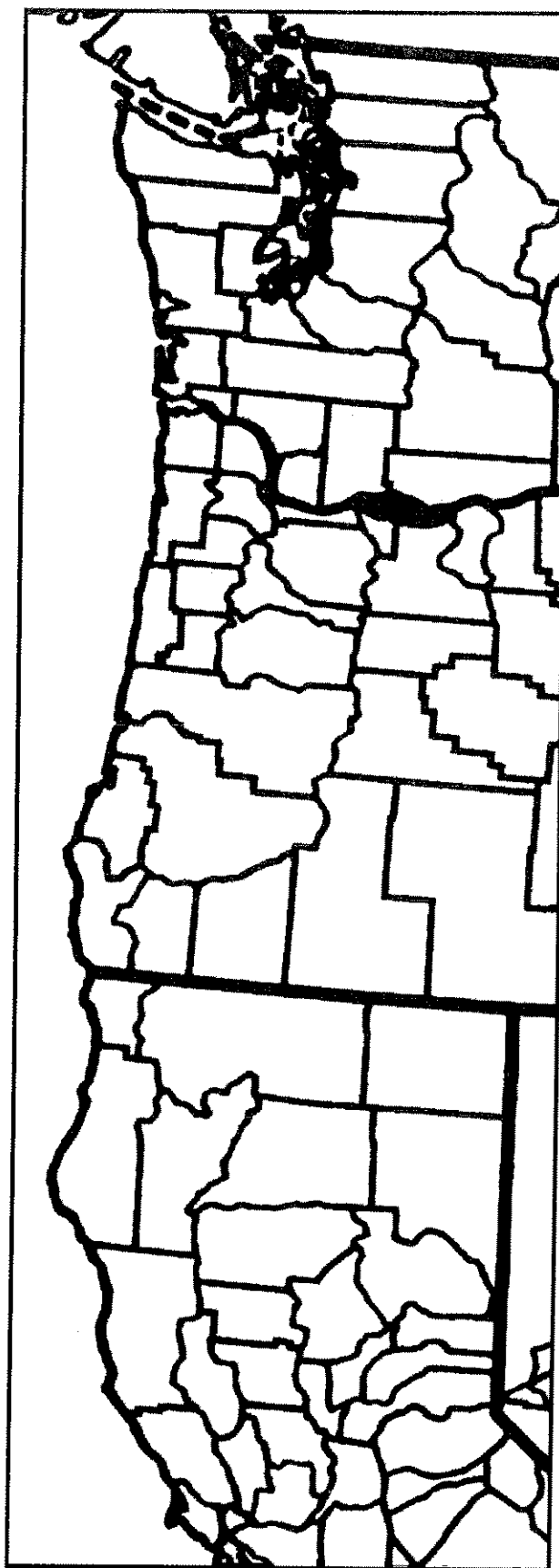


Figure 33. *Juga (Oreobasis)* n. sp.  
2: actual height 22.1 mm.



Figure 34. *Juga (Oreobasis)* n. sp.  
2: actual height 22.1 mm.



Map 16. Distribution of *Juga (Oreobasis)*  
n. sp. 2.



*Juga (Oreobasis)* n. sp. 3

[*Juga (Oreobasis)* n. sp. 6 Frest & Johannes, in press]

**cinnamon juga**

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## DESCRIPTION

Teleoconch medium-sized (**Figures 35 & 36**): typical adult with eroded spire apex with height 14.7 mm, width 7.9 mm; H/W ratio 1.86 (typical individual with eroded apex: smaller individuals not decollate), spire low, short, with barely convex whorls but channeled suture; outermost whorl point definitely below whorl midpoint on teleoconch whorls. Nacre clear royal purple; shell comparatively thin, with periostracal groundcolor even deep cinnamon red in color except for narrow yellowish band immediately below suture on teleoconch in some larger adult specimens; periostracum ornamented with collabral, very weak growth lines; patchy, nearly obsolete striae, if any; many specimens appear almost smooth. Spire often with black, matte mineral/organic coating; periostracum shiny beneath. Initial whorls smooth; moderately high spired and convex, deep reddish-brown. Eroded adults typically retain 4.5-5.0 whorls. Aperture typical rounded lunate; fairly angled adapically; outer lip thin; but shell thickened only very gradually into the peristome and remaining thin; peristome thickened slightly to form very narrow columellar shelf (shelf nacre purple); shelf curved; outer edge of basal lip reflected slightly; parietal lip with thin purplish glaze; shell anomphalous.

## DISCUSSION

This species does not closely resemble any described taxon. The only somewhat similar species is an undescribed taxon known from a few springs in the Deschutes River drainage, Oregon [*Juga (Oreobasis)* n. sp. 3, *q.v.*: see also Key 5]. That taxon lacks the yellow subsutural peripheral band and is smaller, with even more flattened whorls. Recorded under the name *Juga (Oreobasis)* n. sp. in Frest & Johannes (1993d, 1994); as *Juga (Oreobasis)* n. sp. 1 in Frest & Johannes (1995a, 1997); under ***Juga (Oreobasis)* n. sp. 3** in Frest & Johannes (1993c, 1996a); and finally as *Juga (Oreobasis)* n. sp. 6 in Frest & Johannes (in press).

## ECOLOGY

Occurs in large cold springs and spring runs, with sand-cobble substrate or exposed basalt bedrock, associated with one or more endemic *Fluminicola* spp. Epiphytic algae and macrophytes are rare in areas inhabited by this species, although *Rorippa* may be locally abundant, and scattered *Mimulus* common. Water is cold and generally very shallow; flow may be slow-moderate. The immediately surrounding vegetation is mixed pine-deciduous tree/shrub forest; springs with this species are generally well-shaded. This crenophile taxon is mostly a perolithon feeder and lithophile.

## ORIGINAL DISTRIBUTION

Uncertain; recently discovered taxon. Probably Upper Sacramento River springs only.

## CURRENT DISTRIBUTION

Eight sites mostly in a single large nasmode along the central Upper Sacramento River, Siskiyou County, California; one rare occurrence in subaqueous springs in the river itself (**Map 17**; for detailed map, see Frest & Johannes (1995c, map D9)). Localities are very near to Southern Pacific (Union Pacific) Railroad tracks, which have considerably modified the lower part of some springs. Road and trackside spraying and diversion of part of the spring complex have also impacted the known sites. We have surveyed this area extensively between 1991-1996; it is thus very unlikely that future work will substantially increase the range of, or number of sites for, this taxon.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1991-1996.

## FAMILY PLANORBIDAE

### Key 6. Extant Species of *Vorticifex*

[Survey & Manage: *Vorticifex* n. sp. 1, *Vorticifex klamathensis sinitsini* (Baker, 1945)]

Living species of *Vorticifex* (sometimes placed in the separate genus or subgenus *Parapholix*) are mostly poorly studied, aside from some of those dealt with in Baker (1945). Their relationships to the numerous Late Cenozoic forms also need to be clarified. Anatomical discriminants in this group appear to be comparatively subtle. We have retained the current classification, mostly derived from Baker (1945), as the subspecific epithets are likely to be valid; however, certain of the subspecies are likely either to be recognized eventually as full species or to show closer relationships to taxa currently assigned to another species or undescribed.

This genus is a strongly atypical planorbid, being a stream-adapted, cold stenothermal mollusk most typical of cold oligotrophic flowing-water habitats of medium-large size. In some ways, its ecology is much closer to that of the aberrant limpet-shaped lymnaeid group Lancidae (with which *Vorticifex* often occurs) than to stereotypical Planorbidae.

- |   |                                                                                                                                        |                                              |
|---|----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 1 | Shell neritiform, thick; aperture thickened around whole periphery, so that aperture opening evidently constricted .....               |                                              |
|   | ..... <i>Vorticifex neritoides</i> (Hemphill in Baker, 1945)                                                                           |                                              |
|   | Shell thin; neritiform or with low spire; callus at columella and base only .....                                                      | 2                                            |
| 2 | Shell neritiform .....                                                                                                                 | 3                                            |
|   | Shell with short spire or almost neritiform .....                                                                                      | 4                                            |
| 3 | Shell large, to 2.5 cm diameter; very thin, cinnamon-colored; no plicae or periostracal fringes .....                                  |                                              |
|   | ..... <i>Vorticifex klamathensis klamathensis</i> (Baker, 1945)                                                                        |                                              |
|   | Shell large, to 2.5 cm diameter; very thin, yellowish, with prominent regular periostracal fringes and underlying shallow plicae ..... | <i>Vorticifex effusa dalli</i> (Baker, 1945) |
| 4 | Shell with definite spire .....                                                                                                        | 5                                            |
|   | Shell with very low spire or nearly neritiform .....                                                                                   | 7                                            |

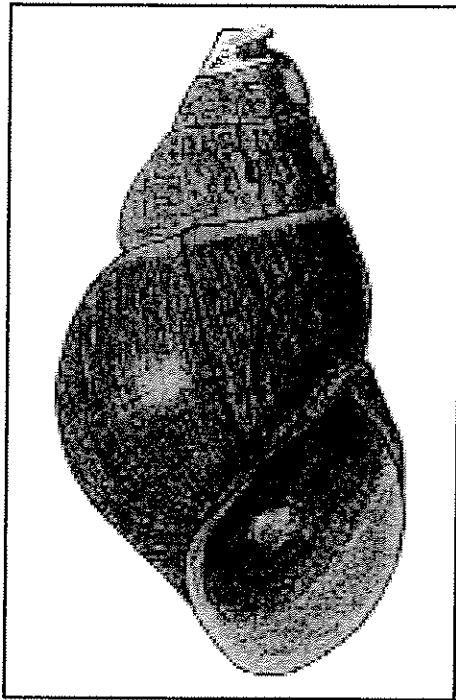
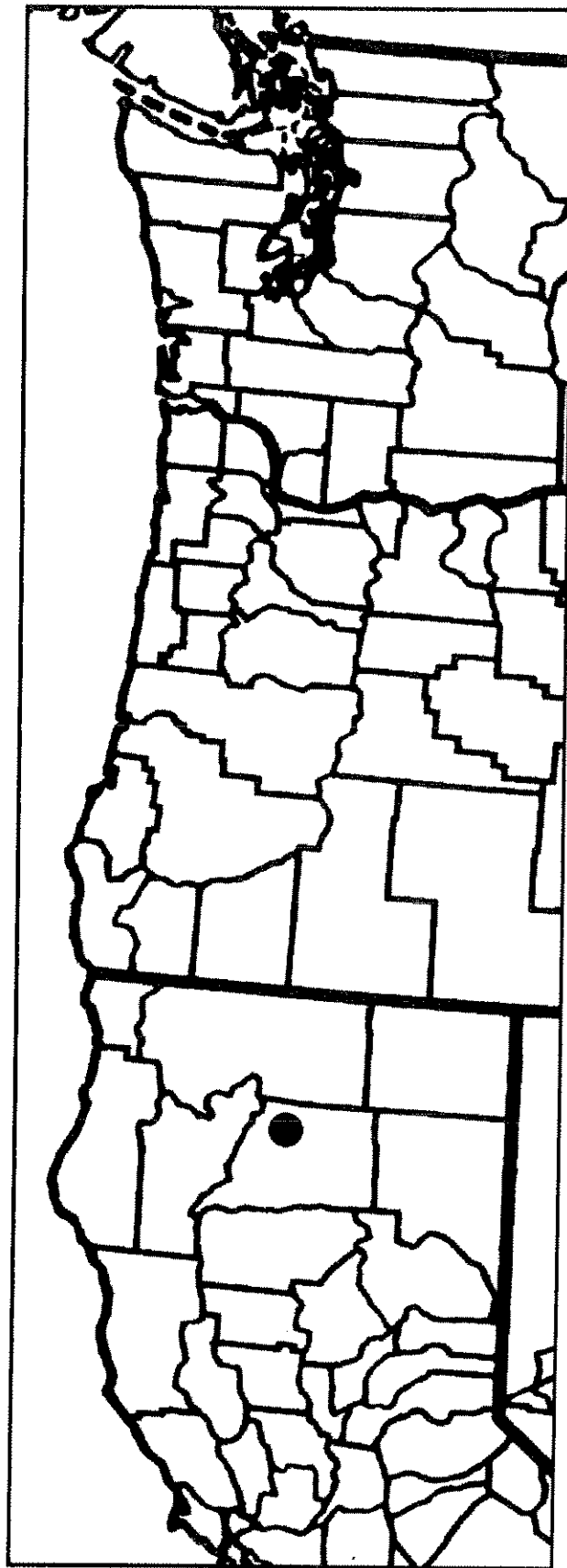


Figure 35. *Juga (Oreobasis)* n. sp. 3: actual height 14.7 mm.



Figure 36. *Juga (Oreobasis)* n. sp. 3: actual height 14.7 mm.



Map 17. Distribution of *Juga (Oreobasis)* n. sp. 3.

- 5 Shell solid but not thick; to 2 cm diameter; juvenile whorls rounded; no plicae ..... *Vorticifex klamathensis sinitsini* (Baker, 1945)  
 Shell comparatively thin; less than 2 cm diameter; prominent plicae or nodes ..... 6
- 6 Shell comparatively thin; less than 1 cm diameter; juvenile whorls strongly keeled; prominent node-like plicae, with or without small periostracal fringes ..... *Vorticifex* n. sp. 1  
 [*Vorticifex* n. sp. 1 Frest & Johannes, in press]  
 Shell comparatively thin; less than 2 cm diameter; juvenile whorls rounded; narrow plicae, with prominent periostracal fringes .....  
 ..... *Vorticifex* n. sp. 2 Frest & Johannes, in press]
- 7 Shell thin to somewhat solid; diameter to 3 cm; with several low diagonal ribs on final whorl .....  
 ..... *Vorticifex effusa diagonalis* (Henderson, 1929)  
 Shell typically somewhat solid; diameter generally 1 cm or less; surface nearly smooth, with very fine growth lines; occasional scattered low periostracal fringes; no varices .....  
 ..... *Vorticifex effusa effusa* (Lea, 1856)

*Vorticifex klamathensis sinitsini* (Baker, 1945)  
[*Vorticifex klamathensis sinitsini* (Baker, 1945)  
Frest & Johannes, in press]

## Sinitsin rams-horn

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### DESCRIPTION

Conch small to medium-sized (height often 5.8-7.0 mm, width 6.2-8.2 mm, H/W ratio 0.81; adults with 3.5-4.0 whorls); spire depressed but elevated in side view due to low protoconch and convex, translated whorls (**Figures 37 & 38**); shell moderately thick for genus, opaque grey-white; periostracum generally opaque, deep reddish-brown but sometimes ranging to rich yellow-brown, thin; often with alternation of lighter areas arranged both spirally and transversely, giving appearance of color bands; often partly eroded from adult specimens, giving spire pitted and crusted look. Periostracal fringes not present; collabral growth lines somewhat fine, irregular and closely spaced; seldom visible on eroded specimens. Spire apex nearly flat; protoconch not visible in side view; 1.2 whorls, diameter 1.6 mm; rounded periphery, but upper surface nearly flat; ornament consists of growth lines only, often eroded in adults. Teleoconch whorls convex; periphery D-shaped; all teleoconch whorls with periphery more or less evenly rounded; but outermost point above midpoint, with lower whorl slightly prolonged and developed ultimately into very subdued, low, rounded basal keel very near columella; last 0.25-0.50 whorl slightly descending. Aperture large, almost D-shaped, constituting 0.79 of shell height; columella nearly straight, with basal half narrower, curved slightly onto shell base; rest of aperture almost parabolic in shape, with shoulder just above aperture midpoint; aperture lip lacking reinforcement except for narrow lunate columellar shelf; but shell thickens within, ca. 3 mm from thinned outer peristome edge; thin glaze across parietal wall; small wedge-shaped areas of overhanging periostracum present near umbilicus and at columellar base in well-preserved material. Shell anomphalous.

### DISCUSSION

For original description, anatomy, and illustrations, see Baker (1945). This subspecies is smaller and has a thicker and more globose shell, with a lower spire, than the nominate form (see also Key 6). Cited under the same name in Frest & Johannes (1993c, 1995a, b, 1996a, b, 1998a, in press).

## ECOLOGY

A crenophile, living in large cold springs with coarse substrate. Macrophytes present commonly may include abundant *Rorippa* and common *Mimulus* and *Veronica*. Water depth ranges from a few inches to 2 feet, flow is moderately rapid. Associated mollusks include *Fluminicola* spp., "*Lyogyrus*" spp., *Helisoma (Carinifex) newberryi* and *Lanx klamathensis*. This taxon is a lithophile and perolithon grazer.

## ORIGINAL DISTRIBUTION

Known at present only from several sites, mostly along the northern and northeastern edge of Upper Klamath Lake, Klamath County, Oregon. Could occur in other springs in the same region, although large numbers of new sites are precluded by recent surveys.

## CURRENT DISTRIBUTION

Originally described from Hagelstein Park (Barkley Spring) but now known from several other sites in the vicinity, as mentioned above (**Map 18**; for detailed map, see Frest & Johannes (1998a, map D13)). A comprehensive survey of the Upper Klamath Lake drainage freshwater mollusks is now under way; the final report is nearing completion (Frest & Johannes, 1995b, 1996b, 1998a, in prep.). Substantial range extension or increment of currently known live sites are both very unlikely.

## REFERENCES

Baker (1945); Frest & Johannes (1993c; 1995a, b; 1996a, b; 1998a; in press); ROD (1994); Deixis collections, 1991-1994, 1996, 1997-1999.





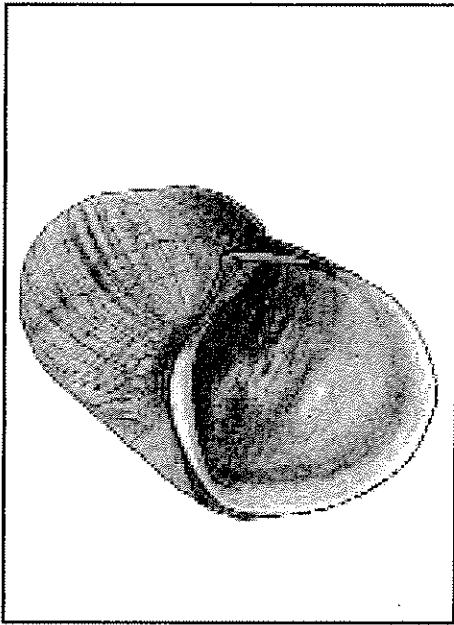


Figure 37. *Vorticifex klamathensis sinitsini* (Baker, 1945): actual height 14.7 mm.

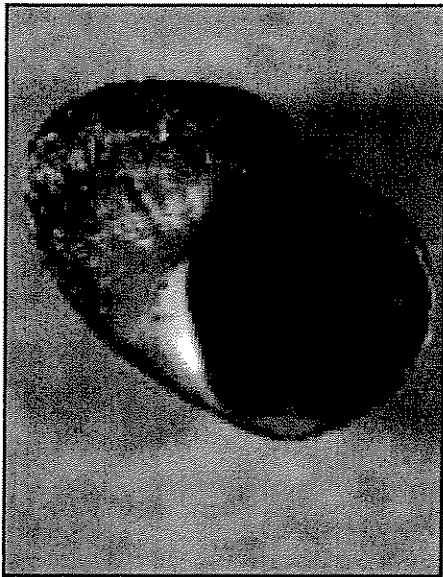
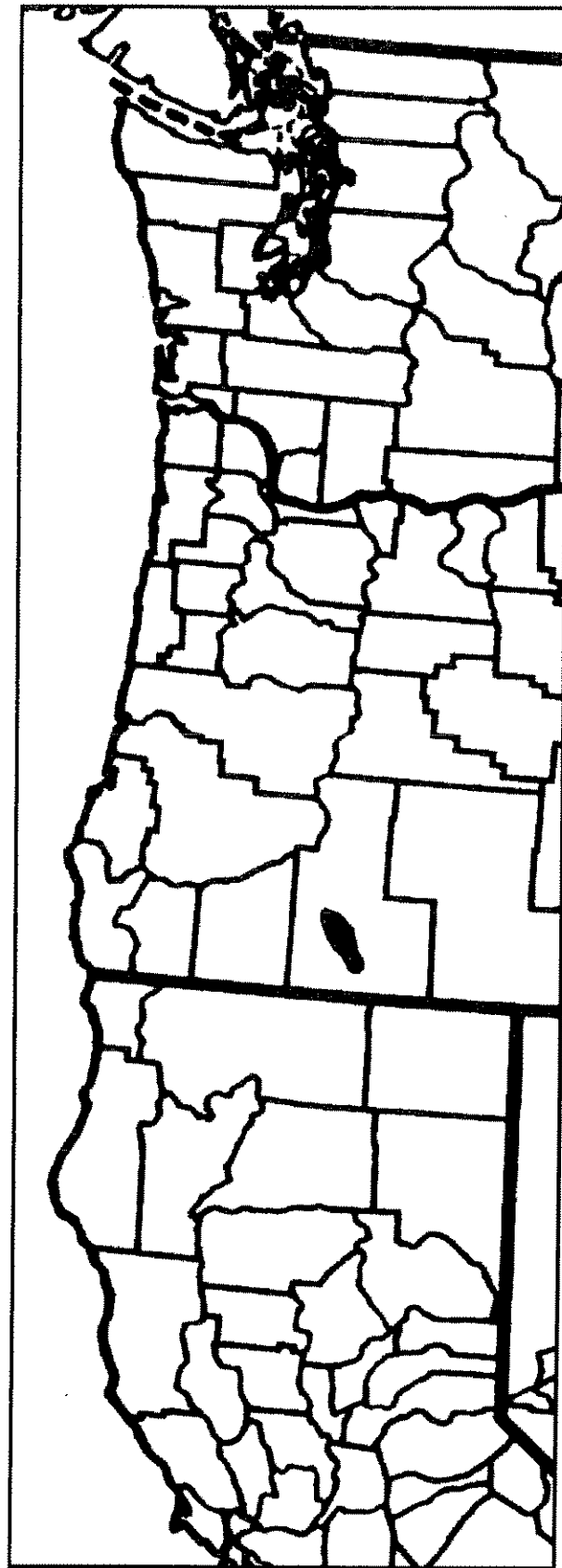


Figure 38. *Vorticifex klamathensis sinitsini* (Baker, 1945): actual height 15.1 mm.



Map 18. Distribution of *Vorticifex klamathensis sinitsini* (Baker, 1945).

*Vorticifex* n. sp. 1

[*Vorticifex* n. sp. 1 Frest & Johannes, in press]

knobby rams-horn

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## DESCRIPTION

Conch small to medium-sized (height often 5.8-7.0 mm, width 5.7-7.0 mm, H/W ratio 1.02; adults with 3.5-4.0 whorls); spire low conoid but distinctly elevated due to strong peripheral keel and shouldered whorls (**Figures 39 & 40**); shell thin, opaque grey-white; periostracum generally opaque deep reddish-brown but sometimes ranging to brown, tan, or yellow, very thin; upper surface nearly flat; protoconch often not visible in side view; 1.2 whorls, diameter 1.2 mm; strong peripheral keel, upper surface nearly flat; ornament consists of growth lines only. Teleoconch whorls also strongly carinate, with carina reduced to rounded, obtusely angular periphery within last half whorl; all teleoconch whorls strongly shouldered above, with outermost point about one-third abapically around periphery; teleoconch also with wide, rib-like, inflated plicae, beginning as nodes but spanning whole periphery by whorl 2; pinched carina also elevated as hollow rib in later whorls in some specimens, often fading as aperture approached; plicae hollow within shell; last 0.25 whorl slightly descending. Morphology otherwise much like *V. effusa* but periostracal fringes subdued, often merely vestigial, on plicae only if present at all; collabral growth lines between and on varices, somewhat regular and widely separated. Aperture large, constituting 0.61 of shell height; rounded D-shaped; columella nearly straight, with basal half narrower, curved slightly onto shell base; rest of aperture almost parabolic in shape, with shoulder just above aperture midpoint; aperture lacking reinforcement except for narrow columellar shelf; thin glaze across parietal wall; small wedge-shaped columellar furrow present, originating about half way up columellar wall and terminating rather abruptly at parietal-columellar wall junction; very narrow, with columellar ridge subdued, little excavation, and columellar grooves obsolete. Shell anomphalous.

## DISCUSSION

No known modern species is similar (**Key 6**). The combination of sharply shouldered (pinched periphery) whorls and knobby appearance is not precisely duplicated in the fossil record, either, although somewhat similar fossil species are known. A possibly related taxon occurs in the Eagle Lake drainage, California; this is termed *Vorticifex* n. sp. 2 in Frest & Johannes (in press). The Eagle Lake drainage *Vorticifex* has narrow hollow plicae and often has prominent

periostracal fringes; the shell may range to 2 cm in diameter; the spire is low conoid but distinctly elevated; juveniles and adults both have the periphery well-rounded. See **Key 6** also. Cited formerly as *Vorticifex* n. sp. in Frest & Johannes (1993, 1994) and as *Vorticifex* n. sp. 1 in Frest & Johannes (1993c, 1995c, 1996a, 1997, in press).

## ECOLOGY

Found only at two sites in limited areas of a very large, pristine spring complex and its outflow, on rocky substrate; very cold and clear water with saturated DO and swift flow. Occurs with abundant *Juga* (*Calibasis*) *acutifilosa*, rare “*Lyogyrus*” n. sp. 8 (ROD: *Lyogyrus* n. sp. 3), abundant *Fluminicola seminalis*, and common *Lanx patelloides*. More or less standard *Vorticifex effusa effusa* is also present in this nasmode in some numbers. Several springs in this complex and those in adjoining nasmodes have typical *V. effusa effusa* only. This spring complex also has (or had until recently) populations of the Shasta crayfish *Pacifastacus fortis*.

## ORIGINAL DISTRIBUTION

Likely confined recently to large spring complexes tributary to the Pit River in Shasta, Modoc, and Lassen counties, California. Similar fossil species are known from the periphery of the Great Basin in Nevada, Oregon, and California.

## CURRENT DISTRIBUTION

Found only at two sites in Shasta County, California (**Map 19**; for detailed map, see Frest & Johannes (1995c, map D38)), on private land adjoining Shasta National Forest. Limited numbers of additional sites are possible in Shasta National Forest, on lands administered by Lassen National Forest, and on state-owned lands near Fall River Mills.

## REFERENCES

Frest & Johannes (1993c, d; 1994; 1995c; 1996a; 1997; in press); ROD (1994); Deixis collections, 1991-1996, 1997.



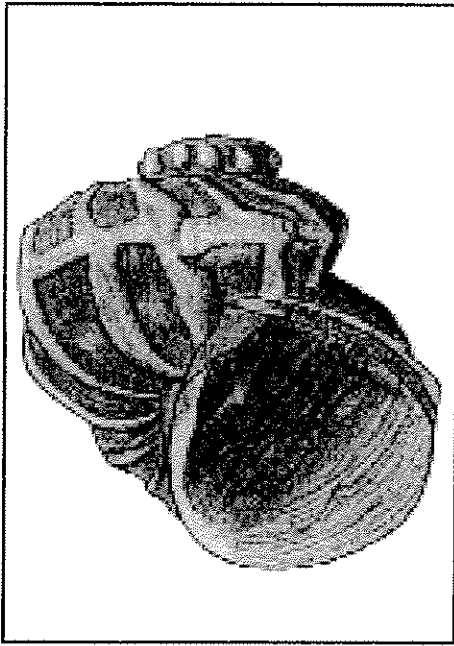
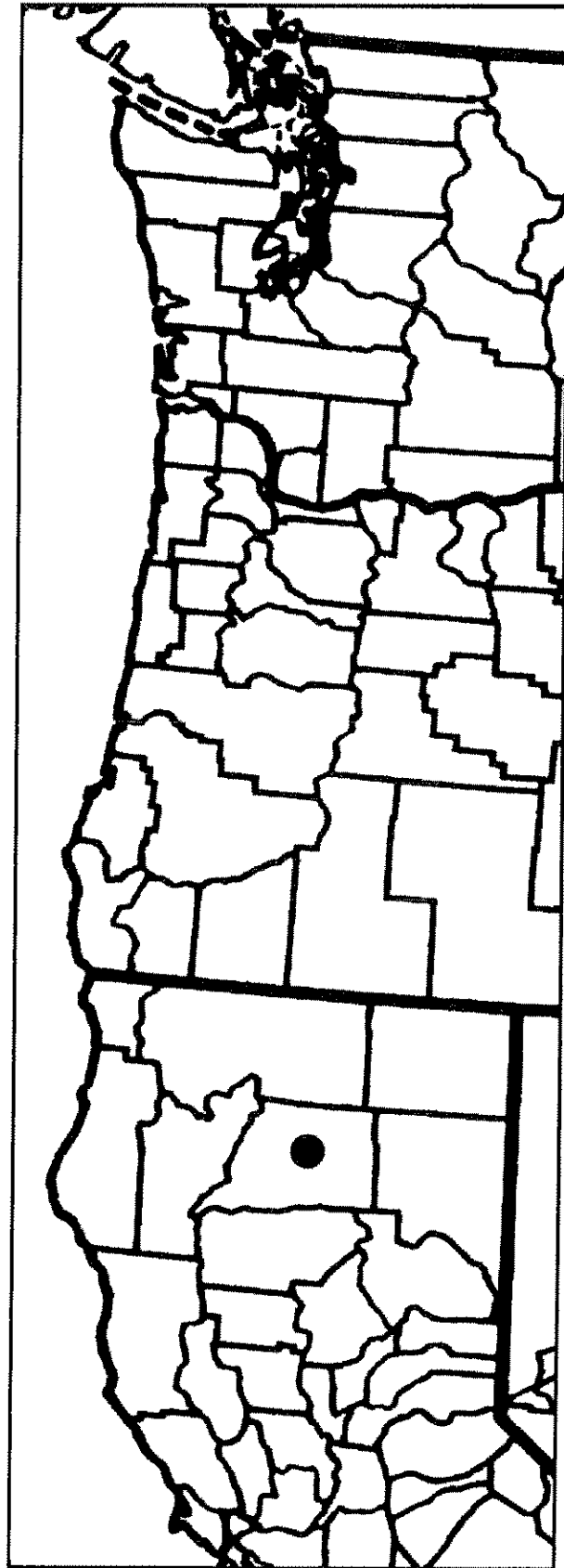


Figure 39. *Vorticifex* n. sp. 1:  
actual height 6.6 mm.



Figure 40. *Vorticifex* n. sp. 1:  
actual height 6.6 mm.



Map 19. Distribution of *Vorticifex* n.  
sp. 1.

## GLOSSARY

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[For other terms, see Arnold (1965), Hershler & Ponder (1998)  
and Frest & Johannes (in press).]

**abapical** (adj.) Directed away from the shell apex.

**abaxial** (adj.) Directed away from the shell **axis** (*q.v.*).

**accessory lobe** (n.) Part of the verge (external male genital system) in such groups as the Hydrobiidae; a lobe other than that bearing the vas deferens (**penial filament**).

**adapical** (adj.) Directed toward the shell apex.

**adaxial** (adj.) Directed toward the shell **axis** (*q.v.*).

**adnate** (adj.) Barely attached to or in contact with; refers generally to contact of last whorl with preceding one. See **appressed**.

**alate** (adj.) Wing-shaped.

**amnicole** (n., adj.) Organism living only in or preferring stream environments; stream dweller.

**amniphile** (n.) Preferring stream environments; river-dweller by preference; **amniphilic** is the adjective.

**angular, angulate** (adj.) Having an angle (or having the tendency to form an angle), rather than a round contour.

**anomphalous** (adj.) With a closed, rather than open umbilicus; see also **phaneromphalous**; **rimate**; **perforate**.

**anoxic** (adj.) Without or very low in dissolved oxygen; said of water bodies. Compare **hypoxic**.

**appressed** (adj.) Well-attached to or clearly in contact with; refers generally to contact of last whorl with preceding one. See **adnate**.

**aperture** (n.) The opening of a snail shell, through which the body protrudes when the snail is active (Burch & Pearce, 1990, fig. 9.3).

**aufwuchs** (n.) The organic coating on stones or other underwater surfaces in permanent water bodies; consists of diatoms, protozoans, small algal epiphytes; fungi; and bacteria. The major food resource for lithophile taxa, and for **perilithon** and **periphyton** feeders (*q.v.*).

**axis** (n.) The central structure of a spiral shell, around which the volutions revolve.

**axial** (adj.) Oriented around, parallel to, or associated with the shell **axis** (*q.v.*)

**basal** (adj., n.) That part of shell peristome opposite the apex; a tooth or lamella located in that portion of the shell aperture. As regards the natural life position, the base is the anterior end. When held with the apex directed upward, the base is the bottom of the shell.

**broadly conic** (adj.) Shell conic, as wide or wider than high.

**cephalic tentacle** (n.) Either of the pair of elongate, flexible organs on the top of the head (base of the snout) of certain freshwater snails; generally with an eye near the lateral base, borne on a more or less distinct lobe.

**collabral** (adj.) Parallel to the lip of a snail shell. Refers to shell sculpture such as ridges, growth lines, or ribs. Sometimes the alternative "transverse" is used (Burch & Pearce, 1990, fig. 9.3). Another commonly seen older synonym is the term "axial".

**columella** (n.) The internal column around which the whorls revolve; the axis of a spiral shell; especially the exposed expression of this structure on the last whorl. The adjective is **columellar**.

**columellar furrow** (n.) Depressed area immediately adjacent to columella, and less often also the parietal edge of the aperture, often crescent- or wedge-shaped, generally excavated (scooped-out or furrowed) to varying degrees, with abolumellar border often developed as **columellar ridge** (*q.v.*); closely spaced prominent growth lines or striae, termed **columellar grooves** (*q.v.*) lie between this ridge and the border of the **columellar shelf** (*q.v.*). Used in regard to shells of Hydrobiidae and other freshwater snail families.

**columellar groove** (n.) Any of several narrow grooves or growth lines situated in the **columellar furrow** (*q.v.*) between the **columellar ridge** (*q.v.*) and the outer edge of the **columellar shelf** (*q.v.*).

**columellar ridge** (n.) Abcolumellar (left) border of **columellar furrow** (*q.v.*), with depressed crescent- or wedge-shaped area of columellar ridges or grooves situated between it and columellar shelf border.

**columellar shelf** (n.) Shelf-like (often flat externally) thickening of shell material deposited along the columella.

**compressed** (adj.) Appearing flattened; relatively planar as opposed to convex: applied to shell whorls, the body whorl specifically, or the shell base.

**concentric** (adj.) Having bands, lines, or the like disposed in even increments around the same center of origin; refers to **operculum** (*q.v.*) morphology.

**conic, conical** (adj.) Said of a shell having approximately the shape of a cone, *i.e.*, tapering evenly from a wide, circular base to a point.

**crenocolle** (n., adj.) Obligate spring dwelling or dweller.

**crenophile** (n., adj.) Preferring to live in springs; snail with such a preference; **crenophilic** is the adjective.

**crescentic** (adj.) Having the shape of a crescent moon; applied to aperture or lamellar shape.

**ctenidium** (n.) An array of pleats or folds, variously developed, situated in the mantle (pallial) cavity of hydrobiids and functioning in dissolved gas exchange (respiration).

**deflected** (adj.) Bent downward from the preceding growth trajectory; most often refers to the final portion of the last whorl of some snail shells.

**depressed** (adj.) Flattened dorso-ventrally (from apex to base); see Burch & Pearce, 1990, fig. 9.5d; often used in combination with other adjectives describing shell shape (see next entry).

**depressed conic** (adj.) Conic shell depressed dorso-ventrally or postero-anteriorly; more specifically, with an apical angle of about 100° (see Burch, 1989, fig. 5e).

**detritivore** (n.) Aqueous taxon feeding on organic particles in sediment.



**dimorphic** (adj.) Having two forms; often referring to mollusks in which different shell morphology characterizes different genders.

**disjunct** (adj.) Refers to whorls or portion of shell not in contact with preceding whorls (portion of shell); detached; loosely coiled shell, wholly or in part, with the whorls not touching one another.

**elongate conic** (adj.) Conic spire with an apical angle of about 30° (see Burch, 1989, figs. 4a, 5b).

**excentric** (adj.) Not placed in the center; refers most often to the nucleus of an operculum.

**glandular areas** (n.) In the Hydrobiidae and related groups, variously morphologically differentiated surficial body tissue, often on the verge but sometimes on the body, believed to have a specialized though presently unknown function.

**globose** (adj.) Shaped like a sphere, *i.e.* with equal width and height and broadly rounded sides (see Burch, 1989, fig. 4c).

**globosely conic** (adj.) Conic spire with an apical angle of about 70° (see Burch, 1989, fig. 5d).

**hermaphroditic** (adj.) Having both sets of functional sexual organs present in the same individual.

**hydrobiid** (n. or adj.) Of or belonging to the mollusks of the family Hydrobiidae; often used formerly almost as a synonym for members of what is now more properly termed the superfamily Rissooidea.

**hypoxic** (adj.) Having low concentrations of dissolved oxygen; refers generally to bodies of water.

**imperforate** (adj.) Having no umbilicus, either due to appression of inner whorls along the shell axis, leaving no central axial cavity; or having such a cavity but in adult shells with a callus or reflected columellar lip completely covering the opening (Burch & Pearce, 1990, fig. 9.10a).

**inflated** (adj.) Appearing swollen; strongly convex as opposed to flattened; applied to shell whorls generally, the body whorl in particular; or the shell base.

**lamella** (n.) [pl. **lamellae**] A calcareous plate, blade, tooth, or scalelike structure on a snail shell; most often refers to such structures located in the shell aperture (Burch & Pearce, 1990, fig. 9.49), particularly those occurring on the parietal (*q.v.*) and columellar or basal apertural sides, those on the outer (or palatal) sides being termed “folds” or “plicae” (Burch & Pearce, 1990, fig. 9.47, 9.49). In the Pupillidae and similar families, the lamellae (or teeth) are termed parietal or angular, subangular; columellar; basal; and palatal(s) respectively (Pilsbry, 1948, fig. 469; Burch, 1962, fig. 83).

**lamellar** (adj.) Acutely rounded as opposed to broadly rounded; plate-, blade-, or scalelike; generally applied to ribs, lirae, or other shell sculptural structures.

**lappet** (n.) A fold, small flap, lobe, or loose hanging portion; generally applied to the lip of a shell.

**lineolate** (adj.) Marked with minute lines.

**lirate** (adj.) Ornamented with sharp, raised threads, marked with parallel grooves or ridges; having thread-like sculpture (**lira**, pl. **lirae**).

**lithophile** (n. or adj.) Animal preferring to live on stones or graze their surfaces; **aufwuchs** grazer.

**malleate** (adj.) Having a hammered-appearing surface (many small, somewhat irregularly-shaped dents or shallow depressions), e.g., like hammered aluminum ware.

**mantle** (n.) The fleshy tunic or membranous covering of a mollusk which secretes the shell.

**multispiral** (adj.) Refers to an **operculum** (*q.v.*) in which there are numerous, very slowly enlarging whorls, spirals, or coils. Compare **paucispiral**; **concentric**; **excentric** (*q.v.*).

**nacre** (n.) The pearly or iridescent shell layer which lines the inside of some shells.

**nasmode** (n.) A set of nearby, generally large springs deriving from a common source; spring complex; spring family.

**nasmodic** (adj.) Having large numbers of springs.

**neanic** (adj.) Early; used especially of whorls; sometimes used as a synonym for embryonic or protoconch whorls; but sometimes refers to immediate post-embryonic teleoconch whorls only.

**neritiform** (adj.) Shaped like *Nerita*; *i.e.* subglobose or hemispherical, with few, rapidly enlarging whorls, very reduced spire, and a heavily callused and expanded parietal apertural margin.

**node** (n.) A knob or swelling; generally on the outside shell surface or aperture periphery.

**oligotrophic** (adj.) Waters with relatively low levels of dissolved nutrients; or more specifically, lakes at an early stage of their development.

**operculum** (n.) A horny (corneous) or calcareous plate borne on the posterior foot of the prosobranch freshwater and certain land snails, which closes the aperture when the snail withdraws into its shell.

**opisthocline** (adj.) With upper end of aperture or peristome (or upper adapical) growth lines, lirae, etc.) oriented backward from the axis (leaning backward from the aperture), as seen in side view. Contrast **orthocline** and **prosocline**.

**orthocline** (adj.) With aperture or peristome termination (or growth lines, lirae, etc.) oriented parallel to the shell axis, as seen in side view. Contrast **prosocline** and **opisthocline**.

**parietal** (adj.) Pertaining to the inside wall of the shell aperture, *i.e.*, that portion in contact with the preceding whorl; that part of the shell aperture formed over or representing the outer wall of the preceding whorl (Burch & Pearce, 1990, fig. 9.3). A lamella developed on this wall is called a **parietal lamella**; also termed **parietal tooth** or **parietal denticle**.

**paucispiral** (adj.) Refers to an **operculum** (*q.v.*) with relatively few whorls, spirals, or coils.

**perforate** (adj.) Having a narrow but distinct umbilicus; compare **rimate**.

**perilithon** (n.) Those organisms growing on stones; usually refers to the smaller (near to microscopic, and consisting of just one or a few cells per individual) and inconspicuous epiphytic algae, diatoms, protozoans, bacteria and fungi, rather than to larger organisms or plants; **aufwuchs** (*q.v.*), in part.

**periostracum** (n.) The thin, proteinaceous outer shell layer, most likely to be pigmented and often not calcareous.

**periphery** (n.) The edge of the shell as seen in outline view (see Burch & Pearce, 1990, fig. 9.7); there are specialized terms for several commonly seen periphery shapes.

**periphyton** (n.) Those organisms growing on submerged stems and other parts of aquatic macrophytes; usually refers to the smaller (near to microscopic, and consisting of just one or a few cells per individual) and inconspicuous epiphytic algae, diatoms, protozoans, bacteria and fungi, rather than to larger organisms or plants; **aufwuchs**, in part.

**peristome** (n.) The thickened rim or lip around the mouth; the lip or margin of the aperture of a spiral shell. The part of the shell surrounding the **aperture** (*q.v.*).

**phaneromphalous** (adj.) Having an open umbilicus; as compared to **anomphalous** (*q.v.*); see also **rimate**; **perforate**.

**photophobic** (adj.) Tending to avoid light.

**plication** (n.) Small fold or corrugation that affects the whole shell but does not thicken it. Also **plica** (s.); **plicae** (pl.).

**post embryonic** (adj.) Those shell whorls formed after the gastropod has hatched from its egg; **teleoconch** whorls. Whorls formed in the egg constitute the **protoconch**.

**prosocline** (adj.) With upper end of aperture or **peristome** (or adapical portion of growth lines, lirae, etc.) oriented forward to the shell axis (leaning toward the aperture), as seen in side view. Contrast **orthocline** and **opisthocline**.

**protoconch** (n.) That portion of the shell of a freshwater snail that is developed in the egg, prior to hatching; also termed embryonic whorls. Ornament and other morphological features of this portion of the shell often differ from those of later (postembryonic) whorls (**teleoconch** or **neanic** (*q.v.*) whorls).

**pseudobranch** (n.) A false or secondarily derived gill; a vascularized fleshy outgrowth near the opening of the pulmonary cavity (**pneumostome**) of aquatic pulmonate snails, which aids in respiration. Not a true **ctenidium**.

**reflected** (adj.) Turned back; refers to edge of **peristome** (*q.v.*) or lip.

**retractive** (adj.) Oriented opposite of the direction of coiling.

**revolute** (adj.) Rolled back; refers to edge of **peristome** (*q.v.*).

**rheocrene** (n.) A flowing spring or spring run.

**rimate** (adj.) Having a very narrowly perforate umbilicus; barely umbilicate.

**rugae** (n., pl.: singular **ruga**, seldom seen) Convex, usually **collabral** (*q.v.*) undulations of the shell surface, roughening it but not as prominently as do ribs. **Rugae** in cross section appear as outward shell undulations, rather than actual thickenings (ribs, lirae (*q.v.*)).

**rugate** (adj.) having a rough or rough-appearing surface.

**s.l.** (adv.) Abbreviation for *sensu late* [Latin], in the broad sense; loosely speaking.

**s.s.** (adv.) Abbreviation for *sensu stricto* [Latin], in the strict sense; strictly speaking.

**snout** (n.) That part of the gastropod head forward of the neck, eyes, and cephalic tentacles, terminating in the mouth and including the buccal mass, radula, and most of the (circumoral) nerve ganglia.

**solid** (adj.) Firm, substantial, as opposed to delicate or thin; said of shell thickness or aspect.

**spiral** (adj.) Coiling around a central axis; coiled around a central point and continually receding from it, with or without concomitant lateral translation; applied to shell form generally, and also to shell sculptural features such as ribs or striae; as opposed to “**collabral**” (*q.v.*) or “transverse”.

**spire** (n.) The whole series of whorls of a spiral shell, excepting the last.

**stenothermal** (adj.) Preferring or adapted to a narrow temperature range. Contrast **eurythermal** (*q.v.*).

**striae** (n., plural; singular **stria** [rare]) A narrow superficial groove or fine furrow on the outer shell surface (Burch & Pearce, 1990, fig. 9.13). Properly refers to negative features only, although sometimes mistakenly used for positive sculptural features, such as fine lirae or ribs, raised above the shell surface.

**subangulate, subangular** (adj.) Refers to a shell **periphery** (*q.v.*) in which the conjunction of the top and bottom [=upper and lower] shell surfaces as seen in profile [=side] view is a rounded angle.

**sulcus** (n.) A relatively broad, shallow furrow on a shell surface.

**suture** (n.) The line of junction or seam along which two hard structures join; a continuous spiral line marking the junction of whorls in a gastropod shell.

**teleoconch** (adj.) The entire gastropod shell except for the **protoconch**.

**thermophile** (n. or adj.) Preferring warm waters.

**trochoid** (adj.) Having the form of a top shell (family Trochidae); coiled and flat-sided; resembling a top.

**tumid** (adj.) Swollen in appearance; broad as contrasted to slender; used in reference to shell whorls generally, the body whorl in particular; or the shell base.

**turbinate** (adj.) Like a *Turbo*; coiled, with a broad base, convex whorls, and a sharp apex.

**umbilicus** (n.) An indentation or cavity or a circular depression at the axial base of a spiral shell; the hollow formed in spiral shells when the inner side of the volutions do not join; the central opening or cavity along the axis of the shell when the inner whorl sides are not appressed (see Burch & Pearce, 1990, fig. 9.3). The adjective is **umbilicate**; other terms describe relative size or proportions more specifically, e.g. **rimate**, **perforate**, etc.

**unionid** (n. or adj.) A member of the bivalve Order Unionida; the larger freshwater mussels, particularly characteristic of eastern and central North America.

**varix** (n.) A **collabral** (*q.v.*: transverse) thickening of the inner or outer wall of a shell. The term is generally limited to a structure that occurs once or a few times during shell growth, as contrasted to regular, closely repeated ribs or striae; often, the term is limited further to rather coarse or large-scale thickenings.

**verge** (n.) 1) In freshwater snails, particularly Hydrobiidae, the external expression of the male genital system, consisting of a penis (with vas deferens) and sometimes of various other associated lobes, ducts, glands, or some combination; 2) in certain land snails, a protuberant copulatory structure at the summit of the penis, ranging from a short, stubby process to an elongate, finger-like structure. The seminal duct is enclosed within it, with the opening (**meatus**, *q.v.*) either terminal or subterminal.

**visceral coil** (n.) That part of the gastropod body above the head and foot, containing the digestive and other organs and usually covered by the shell (not extrudable) that part of the body covered by the mantle.

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